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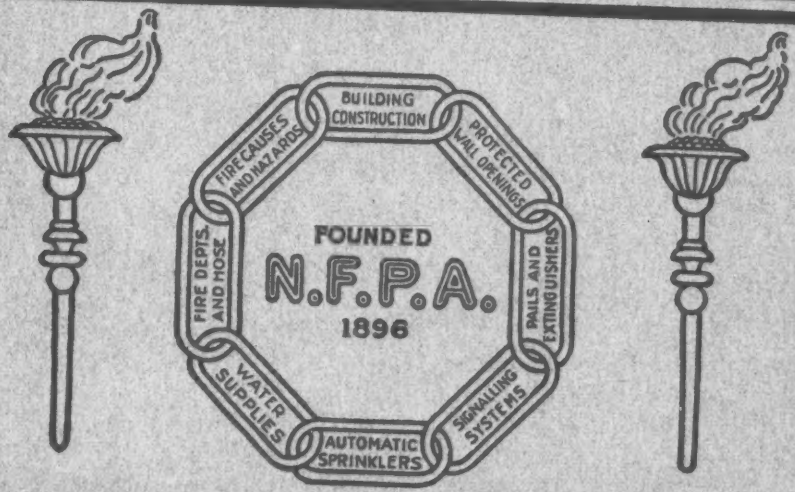
QUARTERLY
OF THE

NATIONAL FIRE PROTECTION ASSOCIATION



"To Promote the Science and Improve the Methods of Fire Protection and Prevention."

PUBLISHED QUARTERLY AT BOSTON, MASS., BY THE
NATIONAL FIRE PROTECTION ASSOCIATION

Printed in U. S. A.

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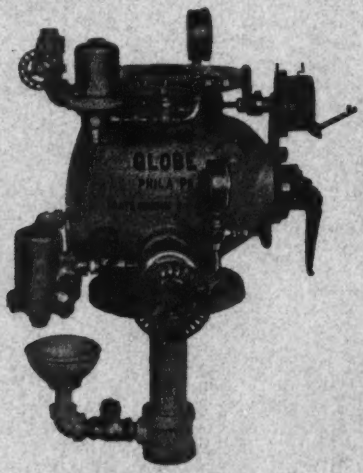

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Vol. 28 October, 1934 No. 2

QUARTERLY

OF THE

National Fire Protection Association

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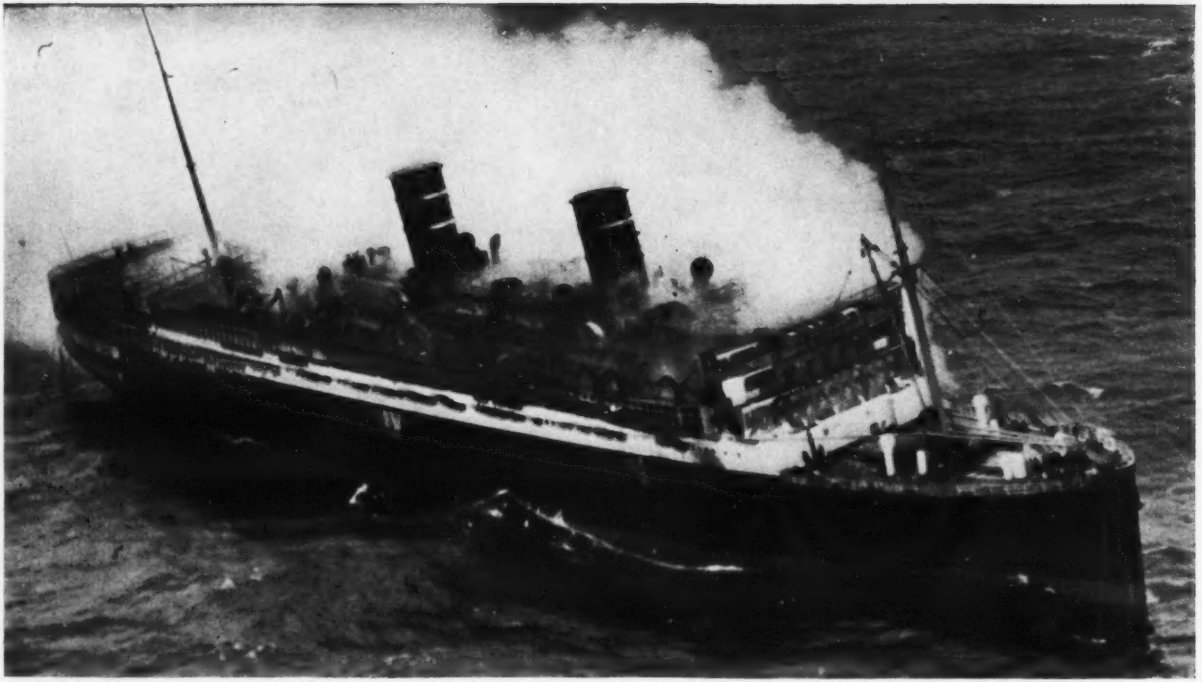
Reports of fires appearing in the Quarterly are copies of or extracts from written reports forwarded to the Association. This Association, as a body, is not responsible for the statements or opinions of any of its members.



International.

Airplane view of the "Morro Castle" on fire off the Coast of New Jersey, September 8, 1934. (See report on page 113). A few members of the crew may be seen huddled in the bow.

The Quarterly

Vol. 28 October, 1934 No. 2

The "Morro Castle" Disaster.

The appalling loss of life in the *Morro Castle* fire, as described in this QUARTERLY, has focused nation-wide attention on the fire hazards of passenger vessels. Characteristic of the investigations of marine disasters, the official inquiries appear to be primarily concerned with the question of personal responsibility. While investigation to establish personal responsibility for fires on shipboard doubtless is a strong influence for a proper attitude toward fire on the part of the personnel, it may sometimes tend to obscure the fundamental factors responsible. The fire protection engineer regards as secondary factors the possibility of incendiarism, and the conflicting reports of the action of the ship's officers, so largely emphasized in the newspaper accounts of the *Morro Castle* fire. He sees two primary factors as fundamental: the large amount of combustible material present in the ship's construction, decorations and furnishings; and the inadequacy of the fire extinguishing facilities.

Before the *Morro Castle* fire, the N.F.P.A. Marine Section, organized last year to extend the activities of the Marine Committee, had already made very substantial progress towards the solution of the fire problem of large passenger vessels. The Marine Committee report published in the Proceedings for 1933 gives detailed recommendations for fire-resistive construction, and a committee report presented at the meeting of the Section held in Atlantic City last May pointed the way towards a satisfactory solution of the problem of installation of automatic sprinklers on shipboard, which involves difficulties of weight and arrangement not found in sprinkler installations on shore. This work of the Marine Section is the coöperative activity of shipping interests, marine underwriters and regulatory authorities, under the able leadership of Chairman S. D. McComb, and has the active support of all concerned.

The *Morro Castle* fire has led to a popular demand for legislation to prevent similar disasters in the future. If the requirements adopted are not the hasty and ill-considered measures so often characteristic of emergency laws, but are consonant with the sound and practical recommendations for fire safety so painstakingly developed in the N.F.P.A. Marine Section, the *Morro Castle* fire may not have been wholly in vain.

Compromises in Fire-Safety. The high-minded individual who declaims "Where safety from fire is at stake let there be no compromise" fails to face the realities. Every N.F.P.A. regulation for fire prevention and fire protection represents compromise decisions in committees, and the practical application of fire-safety measures represents compromise at every step — compromise with cost, convenience, and ignorance. Standards set too high are ignored; set so low as to secure ready acceptance they fall short of accomplishing their purpose. The aim should be to secure reasonable protection from fire, without unnecessary expense or inconvenience. All will subscribe to this aim in principle, but opinions as to what protection is reasonable and what constitutes an unnecessary expense or inconvenience are often antipodal. Thus the utmost of tact, understanding and judgment is required of the fire protection authority who secures truly reasonable fire-safety in the properties with which he has to deal.

A peculiarly difficult problem is that of measures of partial protection. Shall recognition be given to protection which is admittedly inadequate, but better than none? Is the value sufficient to justify the cost? Is there danger that partial protection may give a false sense of security and preclude the installation of adequate equipment? Such questions can be answered, but only on the basis of complete knowledge. As the science of fire protection further develops, and as knowledge is extended, some of our most perplexing problems in this field should disappear.

* * * * * *

Small Hose Couplings. In 1922 the Association adopted a standard for threads for small hose couplings, intended to provide for the smaller sizes the same advantages of substantial, rugged construction, ease of handling and interchangeability that characterize the earlier standard for 2½-in. couplings. No special campaign was waged for the adoption of this standard, but in the dozen years since its first promulgation it has come into extensive use. Replies to a questionnaire circulated in August to fire departments using 1½-in. hose as a part of their regular equipment indicate that the N.F.P.A. standard is followed in 23% of the cities. So-called iron pipe thread and Pacific Coast standard thread are reported from 38% and 23% of the cities respectively, but there is sufficient variation in the dimensions reported to raise a question as to the extent to which couplings supposedly conforming to either of these other standards are interchangeable. Other cities use 1½-in. couplings varying from 1.75 to 2.19 inches in outside diameter of the male thread and from 5 to 12 threads per inch.

During the past year or two questions have been raised as to the relative advantages of the N. F. P. A. small hose coupling standard thread and the fine thread iron pipe type coupling, particularly for standpipe use. This subject was discussed at the last meeting of the Association (Proceedings, 1934,

page 385) and referred to the N.F.P.A. Committee on Small Hose Couplings for further consideration. During the past summer the committee has been enlarged by the appointment of a representative group of new members, and this fall the entire question of small hose coupling threads will be carefully considered by the reorganized committee.

In August the International Association of Fire Chiefs adopted the following resolution at their Milwaukee convention:

Whereas: There was adopted by the National Fire Protection Association in 1922 a standard for hose couplings for 1½-inch hose, which standard is now utilized in many parts of the United States and Canada, and

Whereas: A project is now before the American Standards Association to substitute for the present standard coupling a specification accepting a coupling with a thinner wall thickness and an ordinary fine pipe thread, and

Whereas: In fire department practice it is essential that all hose couplings conform to a single standard, be interchangeable, be strong enough to withstand rough usage, and the thread thereof be coarse enough to avoid injury and crossing in the coupling operation,

It is Therefore Resolved: That the International Association of Fire Chiefs looks with disfavor upon any attempt to depart from or lower the standard of the National Fire Protection Association for couplings of 1½-inch fire hose now adopted and accepted by the National Board of Fire Underwriters, the Associated Factory Mutual Fire Insurance Companies and the U. S. Committee of Manufacturers on Standardizing of Fittings and Valves, and pledges its influence toward the wider general adoption and use of this standard coupling wherever 1½-inch hose is installed for standpipe or fire department use.

Following this action the Pacific Coast Association of Fire Chiefs adopted a similar resolution at their convention in September, and advices have been received that the California state law, which requires the N.F.P.A. standard for all new fire hose couplings, will be actively enforced.

Further report on this subject will be made by the Committee on Small Hose Couplings at the next annual meeting.

* * * * * *

The Flow of Water in Pipes. The hydraulic formulae and tables used for so many years by fire protection engineers are sufficiently accurate for fire protection purposes, but are essentially approximations based upon empirical methods. Since these tables and formulae were first developed research in hydraulic engineering has progressed and refinements have been made which permit the calculation of the characteristics of the flow of water in pipes with a higher degree of accuracy. Recent experiments indicate that there is an appreciable difference in the flow of water, depending upon the temperature, and that the apparent friction loss under otherwise identical conditions may vary several per cent between summer and winter. In a recent paper before the American Society of Mechanical Engineers reporting technical experiments on the flow of water in pipes Professor Charles M. Allen of the Worcester Polytechnic Institute presented the following simile:

"A good illustration would be that of a bird's-eye view of a flock of sheep being driven along a country road, lined on both sides with good feed. The sheep in the middle

will be trotting along, gradually working their way to the side of the road, slowing down in so doing, grabbing a bite to eat and then walking more or less interfered with, finally getting back into the center, and perhaps the next time getting a bite on the other side of the road. The moving sheep present a slightly convex front, as they are traveling faster in the center of the road and almost coming to a stop on the side."

We have never known there was any relation between the flow of water through a pipe and a flock of sheep on a country road, but this simile certainly helps the understanding of friction loss. The comparison may be extended to include the effect both of increased pressure and greater diameter.

* * * * * *

Better Use of Water. Water has been the accepted fire extinguishing agent from time immemorial, but only in comparatively recent times has progress been made in making the most effective use of water. Modern fire extinguishing equipment is infinitely superior to the bucket brigade of a century ago, but even under the best modern practice only a very small percentage of the theoretical extinguishing effect is utilized.

The entire theoretical extinguishing capacity of water can be obtained when all of the water is not only applied at the seat of the fire, but is evaporated, thus having the maximum cooling effect. It is impossible to make any estimate of the exact percentage of water from hose streams that is thus efficiently applied, but it is a reasonable assumption that 90 to 95% of the water from hose streams as ordinarily applied leaks through floors or runs down stairways without contributing appreciably to actual fire extinguishment.

Modern fire fighting technique is constantly improving. The automatic sprinkler extinguishes the ordinary fire with much less water than the large hose stream, and the 1½-in. hose line which is being increasingly used by the fire departments for handling the smaller fires involves far less waste of water and lesser water damage than the large hose lines. Nevertheless there has been comparatively little research to determine ways for securing greater efficiency from water as a fire extinguishing agent. Studies in forest fire protection methods, where the utmost economy in the use of water is usually necessary, may lead to an advance in the science of fire protection in this direction. Recently there has been considerable interest in the use of a new type of nozzle which projects water in a fine spray, supposedly greatly increasing the extinguishing efficiency for certain types of fire. Further exploration of the possibilities of more efficient utilization of water for fire extinguishment presents an interesting field for technical research.

* * * * * *

Fire Prevention Week, 1934. Despite the handicap of business conditions, Fire Prevention Week 1934 has again surpassed previous observances of the week. Requests for Fire Prevention Week literature received by the Executive Office, a barometer of the extent of the interest in the observance throughout the United States and Canada, substantially

exceed those received in 1933. Many of those who have a professional interest in fire protection are every year amazed by the popular interest in the observance of the anniversary of the Chicago fire, which of necessity is nothing more than a reiteration of the elementary principles of fire prevention which have been presented year after year. The extent of the popular interest clearly indicates that what is an old story to the fireman and the fire insurance engineer still has a fresh interest to the greater part of the populace. And it will be only at such a remote time as every man, woman and child may become so thoroughly imbued with the knowledge of fire prevention that the practice of fire prevention is universal during the fifty-two weeks of the year, that the annual observance of Fire Prevention Week will become unnecessary.

The Morro Castle Fire.

Early on the morning of September 8, 1934, as the luxury liner *Morro Castle* of the Ward line was approaching New York Harbor on her return trip from a pleasure cruise to Havana, fire broke out in the passengers' quarters on an upper deck. The result was the worst marine disaster of recent years. Of the 548 passengers and crew aboard, one hundred and twenty-four are dead or missing. The ship, completely gutted, rests in the sand on the beach at Asbury Park, N. J.

The testimony of witnesses at the inquiry conducted by the United States Steamboat Inspection Service has been confused and conflicting, but at the same time it has clearly indicated that the fire may be primarily chargeable to the large amount of combustible material used in the construction of the ship and furnishings, and that its spread beyond control was due to the lack of an organized fire fighting force, automatic fire protection equipment, or both.

The complete story of the disaster may never be known. The fundamental questions are how and why the fire started and spread so rapidly, why it was not controlled with the ship's fire fighting equipment, and why the passengers and crew did not promptly take to life boats, and thus avoid loss of life.

Description of the Ship and Fire Protection.

The *Morro Castle* was built in 1930 at a cost of $4,800,000 and with a sister ship, the *Oriente,* was considered the finest and most luxurious vessel ever placed in coastwise service. The vessel had an overall length of 508 feet,

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This account has been prepared from reports of the evidence presented at the inquiry conducted by the U. S. Steamboat Inspection Service. This constitutes the best information available at the time of this writing.—Ed.

was of 11,520 gross tons register and had twin screws with turbo-electric drive. Accommodations were provided for 490 passengers.

The construction and fire fighting equipment of the ship were in accordance with current good practice at the time the vessel was built. Like most passenger vessels, however, although the hull and superstructure were of steel, there was a large amount of wooden and other combustible construction in the superstructure and passengers' quarters. Stateroom partitions were of plywood and the lounges, dining saloons and other public rooms had elaborate decorative finish and trim of a combustible character. Furnishing and draperies were also elaborate and, of course, combustible so that there was no lack of fuel for a fire.

The arrangement of the passenger section of the ship had most of the usual defects which permit a fire to spread rapidly from its point of origin. The main stairways, with combustible trim, were open from deck to deck. Fire retarding partitions with fire doors were provided at 130-foot intervals on each deck, but the doors required manual operation and the evidence indicates that the crew received little or no instruction in their operation.

The ship's hold was protected by smoke detectors and by a carbon dioxide gas fire extinguishing system. A carbon dioxide system also protected the boiler and engine rooms. Staterooms, officers' quarters, and radio room were protected by an automatic fire alarm system, but there were no thermostats in the writing room where the fire started or in the adjoining lounge. There is no evidence of failure of the fire alarm system.

For fire fighting, soda-acid type fire extinguishers and a standpipe and hose system were provided as required by the U. S. Steamboat Inspection Service. The standpipe and hose system was supplied by two electrically driven centrifugal sanitary and fire pumps having a capacity of 300 and 400 gallons per minute each, and a steam driven fire and bilge pump of approximately 300 gallons per minute capacity — sufficient to supply four or five good fire streams at one time.

Life-saving equipment consisted of ten 30-foot metal life boats having a capacity of 70 persons each, two 30-foot motor life boats carrying 63 persons each, and twelve 16-person life rafts. An instruction card posted on the inside of each stateroom door instructed the occupant as to the location of life belts and his proper boat station in event of collision or fire.

Story of the Fire.

Early on the morning of September 8 the ship was off the New Jersey coast on the last night of its run from Havana. The sky was overcast and a choppy sea was running. The wind was east, off the starboard quarter. Most of the passengers had retired to their staterooms, although a few of them were still in the lounge, café or other social rooms.

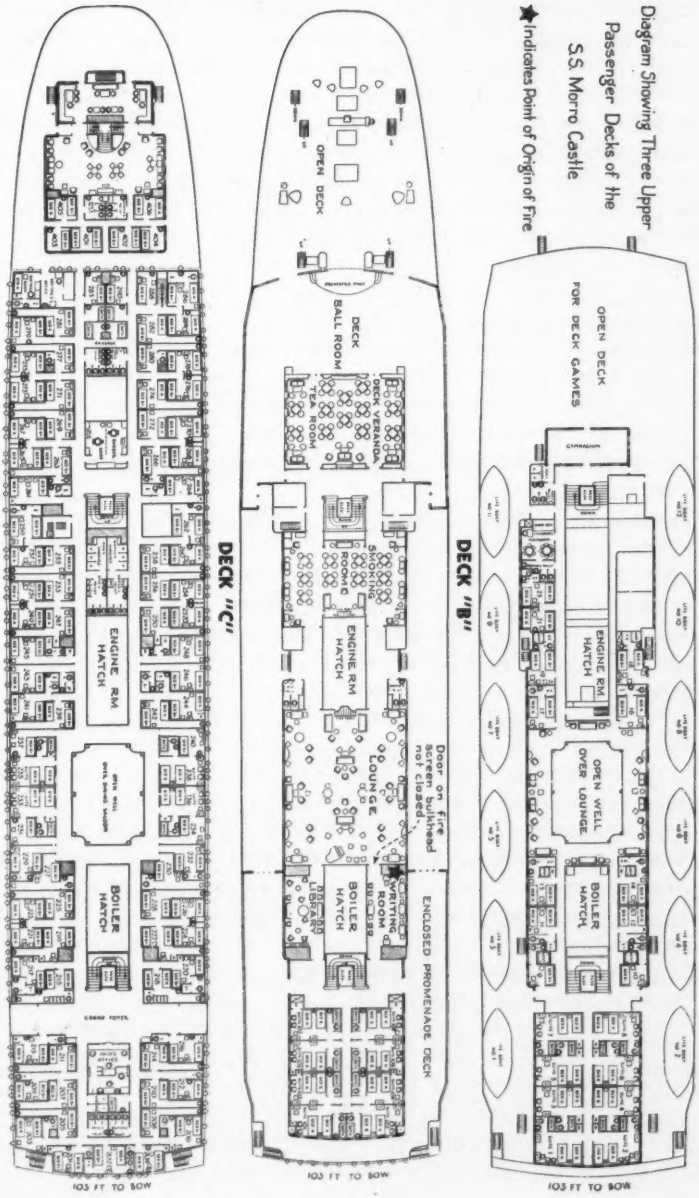


Diagram Showing Three Upper Passenger Decks of the S.S. Morro Castle
★ Indicates Point of Origin of Fire
DECK "A"
OPEN DECK FOR DECK GAMES
GYMNASIUM
ENGINE RM HATCH
OPEN WELL OVER LOUNGE
BOILER HATCH
103 FT TO BOW
DECK "B"
OPEN DECK
DECK BALL ROOM
DECK VERANDA
TEA ROOM
SMOKING ROOM
ENGINE RM HATCH
Door on fire screen bulkhead not closed.
LOUNGE
WRITING ROOM
BOILER HATCH
ENCLOSED PROMENADE DECK
103 FT TO BOW
DECK "C"
ENGINE RM HATCH
BOILER HATCH
103 FT TO BOW

Sometime before three o'clock (Eastern Standard Time) Donald Campbell, assistant beverage steward, was in the smoking room when a passenger reported the odor of smoke. According to Campbell's testimony, he proceeded through the lounge to the writing room on the port side of B Deck, where he discovered a locker all ablaze. This locker, used for storage purposes, was built into the wall of the room, near the door to the lounge. Campbell states that he informed the night watchman of the fire, telephoned the steward and then returned with a fire extinguisher. By this time the fire seemed to have spread considerably.

In the meantime, the deck watchman notified the ship's officers on the bridge and the Second Officer was sent to investigate. This was at 2:45 A.M. This officer testified that he used a fire extinguisher on the fire for approximately five minutes, but it continued to spread rapidly to the walls and ceiling around the locker and he returned to the bridge to sound a general fire alarm. This alarm was recorded at about 2:55 A.M. Several passengers testified that they sounded alarms from manual fire alarm boxes provided in the corridors of the ship, but no testimony relative to the receipt of these alarms has been reported.

Meanwhile a member of the crew put a hose stream in operation, but the fire was apparently beyond the control of a single stream. Other hose lines were brought into use by other members of the crew and passengers. Some of these were directed on the fire through the forward doorway to the writing room; others through windows leading on to the deck, which were broken for this purpose; and still others through the upper windows of the lounge on A Deck.

The lack of fire fighting experience on the part of those who were fighting the fire was evidenced by their permitting so many openings to be made between the burning rooms and the outside air and the utter disregard of the doors in the fire-screen bulkhead which was provided primarily for the purpose of cutting off a fire and confining it within specific limits. Both of the doorways of the writing room were open and with the gale of wind that was blowing there is little difficulty in accounting for the rapid spread of the fire to the lounge adjoining. The lounge was a large elaborately furnished room, which extended the width of the ship and was two decks high, with a mezzanine at the deck above. This allowed the fire and smoke quickly to involve two decks and spread fore and aft on both.

The doorway between the writing room and the lounge was provided with a manually operated fire door, but the testimony indicates no attempt was made to close it. At least one witness stated that the rapid headway of the fire made it impossible to reach it, while another stated that it was kept open to facilitate fire fighting operations. No mention has been made in any of the published accounts of the official hearings as to why no attempt was made to

Wide World.

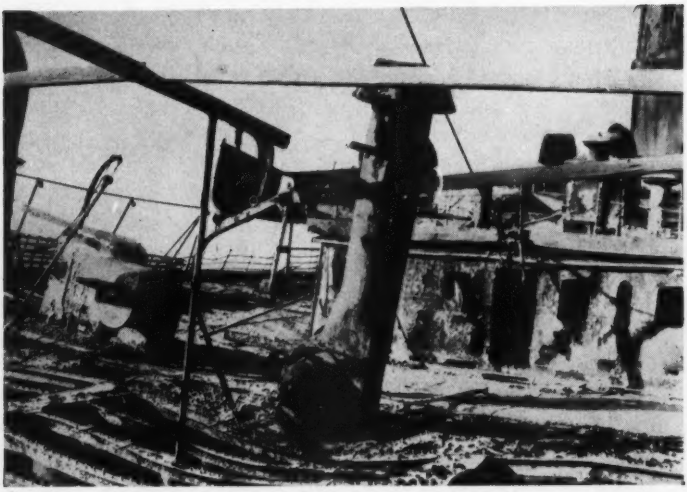
As rescue vessels approached the burning "Morro Castle" dense clouds of smoke enveloped the ship from bridge to stern, completely obscuring the superstructure.

close the fire doors in the next fire-resisting bulkhead, just beyond the lounge, 130 feet farther aft.

Even before the fire had extended very far beyond the writing room, considerable heat and smoke had been generated. When the ship was brought about in an attempt to reach the Jersey shore, shortly after the sounding of the general alarm, the smoke and flames were driven forward, forcing back the passengers and crew who were attempting to fight the fire with hose streams from the forward stair hall. This is indicated by the fact that numerous signals were received on the bridge at about this time from stations on the automatic fire alarm system in the stateroom area forward on A and B Decks.

In the meantime the smoke vented through the upper part of the lounge to the Boat Deck and was drawn down through the ventilators into the boiler and engine rooms. Conditions below in the engine room became unbearable at 3:31 A.M., when power was shut off and preparations made to abandon the engine room. The last man left the room at 3:40 A.M. It also appears that the main electric cable burned out at about 3:29 A.M., causing the lights to fail all over the the ship.

When the engines were stopped an anchor was dropped and the ship again headed up into the wind, driving the fire aft with renewed vigor. With the failure of the electric supply and the abandonment of the engine room, fire fighting efforts virtually ceased, although it is apparent that one or more hose streams fed by the 300-gallon per minute capacity steam pump were used by passengers or crew members on the lower decks to hold off the approaching flames until rescues could be effected. Testimony regarding the effectiveness of the hose streams was controversial, but with at least ten standpipe outlets



Acme.

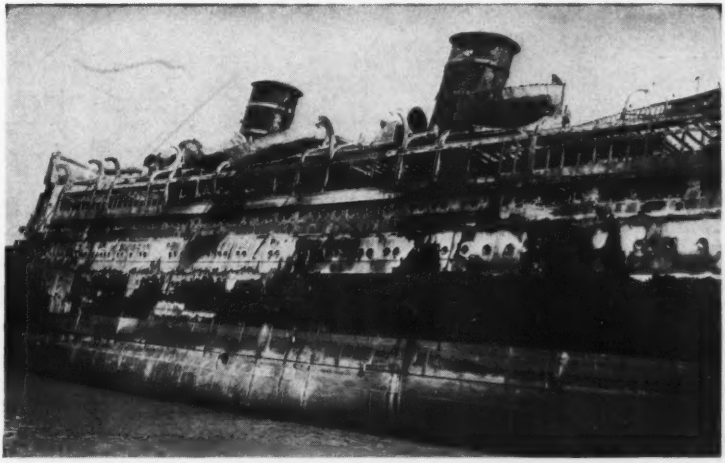
Ruins on A Deck looking forward. Note complete destruction of all combustible construction including plank deck, and distortion of steel members.

open (as indicated by an examination of the ship after the fire) it seems improbable that any very effective streams could have been supplied for long by the 300 g.p.m. steam fire pump still in operation.

Rescue Work.

No organized efforts were made by the crew to advise passengers of the fire and in the darkness it is not surprising that all the elements of panic were present. Eyewitnesses state that smoke filled the corridors on the stateroom decks in an incredibly short time. The fire probably trapped some persons in their staterooms as it spread. Others got out of their rooms, but were driven to the after decks by either smoke or fire.

The failure of passengers to reach life boats, while to some degree chargeable to panic and lack of knowledge of their boat stations, was principally due to the fact that either smoke or flames had cut off both of the main stairways, fore and aft. With these exits cut off, the only approach to the top or boat deck where the life boats were located was by outside companionways aft and a service stairway forward, which latter was used by the crew in effecting their escape. The outside companionways aft were enshrouded in smoke, and little effort was made on the part of crew members to direct passengers to the service stairway by which they might have reached the boat deck. Most of the crew below and a few passengers reached the boat deck, however, and were able to get away from the burning ship in life boats. None of the boats were lowered until after the ship had been stopped.



Acme.

The fire-swept "Morro Castle" beached at Asbury Park, N. J. The extent of the fire is indicated by the discoloration of the steel hull.

At 3:15 A.M. the radio operator sent out a CQ (stand-by) signal and a few minutes later an SOS signal was sent out. Testimony at the hearing indicates that these signals were not sent until after another ship had observed the fire and inquired of shore stations if a fire at sea had been reported. There were a number of ships in the vicinity and several, the *Andrea F. Luckenbach*, the *City of Savannah* and the *Monarch of Bermuda*, were soon on the scene to render aid along with various smaller craft and Coast Guard boats. The rapid spread of fire, however, had driven most of the passengers and some of the crew to the stern from which those who were still alive were forced to jump into the sea or slide down ropes as the smoke and increasing heat became unbearable. Most of those who remained on the lower decks of the doomed ship until rescue vessels approached about daylight were picked up. Many others were drowned or burned to death. A few, clinging to wreckage or swimming, reached the New Jersey shore, about eight miles distant.

The total number of persons aboard the ship when the fire occurred was 548, of whom 316 were passengers and 232 members of the crew. The total number known to be dead or missing was 124, of whom 89 were passengers and 35 crew members. This leaves 424 survivors — 227 passengers and 197 crew. Of the survivors, 166 were reported as taken off by the three major rescue ships, the remainder were rescued by the numerous smaller vessels or reached shore in life boats or by swimming.

Notable Passenger Ship Fires Since 1900.

The following list of the more noteworthy passenger vessel fires since 1900 has been compiled from the files of the N.F.P.A. Department of Fire Record.

Date	Ship	Location	Loss	Lives Lost
June 30, 1900	S.S. Kaiser Wilhelm der Grosse, Main, Saale and Bremen	Hoboken, N. J.	$4,627,000	300
June 15, 1904	S.S. General Slocum	East River, New York, N. Y.	70,000	1021
Oct. 19, 1913	S.S. Volturno	Atlantic Ocean	"Total"	136
July 15, 1921	S.S. Mauretania	Southampton, England	"Large"	....
Oct. 10, 1924	S.S. President Polk	Brooklyn, N. Y.	500,000	1
Jan. 2, 1925	S.S. Mohawk	Off Delaware Coast	"Large"	....
Mar. 19, 1925	S.S. Bienville	New Orleans, La.	1,000,000	....
Mar. 10, 1926	S.S. America	Newport News, Va.	1,000,000	....
Mar. 26, 1929	S.S. Europa	Hamburg, Germany	3,000,000	....
Aug. 19, 1929	S.S. Paris	Havre, France	375,000	....
Feb. 11, 1930	S.S. München	New York, N. Y.	2,000,000	....
June 25, 1930	S.S. City of Honolulu	Honolulu, T. H.	1,750,000	....
June 18, 1931	S.S. Bermuda	Hamilton, Bermuda	2,430,000	1
Nov. 19, 1931	S.S. Bermuda	Belfast, Ireland	4,250,000	....
Dec. 20, 1931	S.S. Segovia	Newport News, Va.	3,500,000	....
May 16, 1932	S.S. Georges Philipar	Off Coast of Italian Somaliland	6,150,000	40
Nov. 14, 1932	M.S. Pieter Cornelis-zoon Hooft	Amsterdam	3,500,000	....
Jan. 4, 1933	S.S. Atlantique	English Channel	18,000,000	18
Nov. 29, 1933	M.S. Indrapoera	Rotterdam, Holland	"Large"	....
Sept. 8, 1934	S.S. Morro Castle	Off New Jersey Coast	4,300,000	137

Demolition of Dilapidated Buildings.*

Old dilapidated wooden buildings have always been an important factor in the loss of life and property by fire in the United States and Canada. However, it is only within the last few years that a large number of cities have sensed this fact and have waged campaigns to secure their demolition. In the first few months of 1934 this work gained impetus and many cities and towns made use of technically trained men employed under the Civil Works Administration (CWA) in conducting surveys of buildings to determine their safety.

The following discussion shows the organization and operation of two programs to secure the removal of unsafe buildings. The first program, that of Chicago, secures the demolition of unsafe structures through the consent of the owner, thus eliminating legal difficulties. The account of the Milwaukee program shows the success of an intensive demolition program by condemnation proceedings.

Demolition by Consent of Owner—Chicago.

The Chicago campaign of demolition by consent of the owner is interesting because of the coördinated effort of some half dozen official and unofficial agencies to secure the demolition of 2000 unsafe buildings. A CWA survey (based on minimum requirements of the state and city sanitary and building codes) of some 6000 suspected buildings revealed that 4000 needed major repairs, and that 2000 were beyond repair and unsafe. Because of legal red-tape, city authorities have been considerably hindered in securing condemnations. The physical problem of demolishing a structure is always the most simple factor in such programs.

In the past the normal procedure was for the building commissioner to condemn buildings which were determined to be dangerous to life and property. If the owner did not remove the structure after being notified to do so, the building department called for bids by mailing notices to recognized wreckers. Wreckers asked from $50 to $300 to wreck buildings, since the salvage was supposed to be left on the premises as property of the owner. In emergency cases the fire department razed the building by putting a rope around it and pulling it down with a truck. In either case the salvage was usually carried away by vandals and only a pile of rubbish remained. If, on the other hand, the owner acted upon the notice of the building department, he might enter into a contract with a wrecker to do the work in return for the

*Data on the Chicago program have been extracted from an article appearing in the *Engineering News-Record* of July 19, 1934. The Milwaukee account and photographs have been supplied through the courtesy of Leon M. Gurda, Inspector of Buildings, Milwaukee, Wisconsin.

Dilapidated structures condemned and awaiting removal. Note severe exposure to windows of adjoining brick buildings.

salvage material, if it was a frame building. If of brick, however, the wrecker usually charged from $50 to $300, since there is small salvage value.

The difficulty with demolition by condemnation is inherent in the Illinois Cities and Villages Act, which permits the police power to be exercised *only* when a structure is ready to collapse. If the building commissioner should condemn a building and effect its razing before this stage is reached, he may be sued by the owner, who might collect from the commissioner's bondsman. The health commissioner has a wider latitude in condemnation, but boarding-up doors and windows of an unoccupied house usually satisfies his legal requirements. To strengthen the powers of both commissioners, amendments to the Cities and Villages Act are being drawn to present to the next session of the state legislature.

To offset this difficulty the Metropolitan Housing Council was formed early this year as a correlating body with representatives of engineering and architectural societies, social service agencies, financial and real estate interests, improvement associations, and all the governmental agencies involved, such as the Illinois State Housing Board, City Housing Authority, building and health commissioners, Civil Works Administration, and Illinois Emergency Relief Commission.

The State Housing Board, a tax supported body authorized to clear blighted areas in making provision for future housing, takes part in the demolition-by-consent program by requisitioning for laborers from the Illinois Emergency Relief Commission, and calling for bids from licensed wreckers. The State Housing Board selects the successful bidder, who executes a con-

tract not with the Board but with the owner direct. This keeps the Board from getting involved in the details of the house-wrecking business. The bidder furnishes general superintendence, tools and equipment, and trucks to haul débris from the site. He also agrees to include premiums on insurance policies covering workmen's compensation and liability insurance. This last requirement causes considerable difficulty in putting relief men to work on useful projects, since neither state nor federal relief money can be used to pay insurance premiums. By consent of the owner the salvage goes to the wrecker.

A serious fire hazard and unfit for habitation, this condemned Milwaukee structure was razed through the efforts of the Building Department.

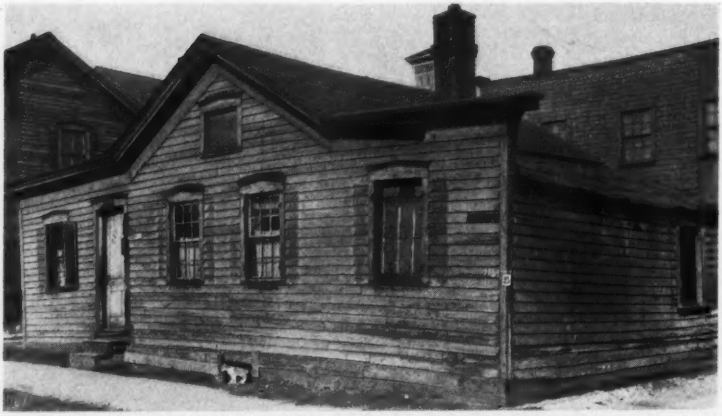
The first part of a wrecking contract is for the owner to request the State Housing Board for demolition. Owners are invited through publicity of the various agencies to offer their useless buildings for demolition. Formerly the owner had to seek a demolition permit from the building commissioner, costing a minimum of $5 per structure. The Metropolitan Housing Council was instrumental in getting a city ordinance passed waiving the permit for these "consent" cases, the only requirement being that the wrecker notify the commissioner's office for record purposes.

The second part of a wrecking contract is the acceptance by the wrecker. All legal work is carried out in the office of the State Housing Board. All wreckers in Chicago are licensed, and the workers are strongly organized. Generally speaking, union men are employed, draw union rates, and are permitted to work long enough to earn their "relief budget."

Demolition by Condemnation—Milwaukee.

A survey was made in Milwaukee early this year for the purpose of drawing up a comprehensive plan of condemnation and demolition of unsanitary, unsafe, and dilapidated buildings. The information collected is also valuable to the building inspection department when issuing permits for occupancy and use, or for repairs and alterations to these buildings.

Out of a total of 168,710 buildings in the city, 133,866, or 80 per cent, are of frame construction. The survey, however, was limited to frame buildings in the most congested fire zone areas, which constituted approximately



Thirty per cent of the frame buildings surveyed in Milwaukee were of old construction, dry rotted in parts, out of plumb or unsafe because of this condition or manner in which they were used.

1028 city blocks with about 17,759 frame buildings. It was believed that the building and living conditions in this area constituted probably the greatest evil, both from a health and fire hazard standpoint.

The survey has not yet been completed, but the area thus far covered shows that 60 per cent of the buildings are of frame construction, 29% of masonry construction, and 11% of fire-resistive or slow-burning construction. Of the 2659 frame buildings reported, 57% had masonry foundations, while 26% were erected on wood posts, and 17% were built directly on the ground, with no foundations. The physical conditions of these frame buildings were as follows:

	Per Cent
Excellent (new construction and sound)	2
Good (old construction, sound, good appearance)	26
Fair (old construction, sound, dilapidated appearance)	42
Bad (old construction, dry rotted in parts, out of plumb or level, unsafe because of condition or manner in which used)	22
Extremely bad (old or new construction, unsound, liable to collapse)	8
	100%

The survey revealed that 804, or 30% of the frame buildings, were subject to condemnation orders and demolition thereafter. It also indicated that if the survey in the fire area alone were completed there would probably be found approximately 6000 buildings classed as bad or extremely bad.

Many other violations of ordinances, such as unsanitary conditions and occupancy and use were found. Thirty-six per cent of all bedrooms in use were illegal, in respect to area or ventilation; and 50% of all housing units were not provided with bath tubs.

Over sixty years old, in poor condition and highly combustible, these buildings were ordered demolished. An appeal to the Courts upheld the action of the Milwaukee Building Inspector in condemnation proceedings.

Many owners have voluntarily razed their buildings to escape payment of taxes thereon, when it was evident that the incomes from their outworn buildings were insufficient for even their upkeep. However, many more buildings are in a deplorable state, as this report discloses, and condemnation proceedings under the city's police power and state statutes have to be resorted to in practically every case. Such action does not expeditiously remedy a bad situation, especially if many legal difficulties are encountered.

Definite policies are followed in securing demolitions to avoid legal trouble wherever possible. Great care is exercised before a building is condemned. The rule followed for dilapidated and unsanitary buildings of a type of construction not permitted in a certain area is that if the cost of repairs exceeds 50% of the replacement cost of the building (exclusive of good masonry foundations) it should be ordered razed.

Orders are served on the owner, lien holders, mortgagees and tenants; allowing a reasonable time (usually 20 days) for compliance. If not complied with, a second and final notice is served with a time limit of 10 days. If it is necessary to contract for razing a building, contractors are asked to submit two bids: (1) to raze the building and remove the material, and (2) to raze the building and pile the material on the premises. The less expensive bid is usually accepted.

An important case (Joseph S. Eigel, plaintiff vs. Leon M. Gurda, as Inspector of Buildings for the city of Milwaukee, Wis., defendant), upholding the power of condemnation was settled in the circuit court of Milwaukee County

in May of this year. Property of the plaintiff, a one-story frame garage and two two-story frame storage buildings, was located in the fire district. They were over 60 years old and composed entirely of combustible material. Sills and supporting members were decayed and weak, walls were warped and bulging, and the shingles on the roof were curled and loose. The buildings were determined by the inspector of buildings to be beyond repair and a fire hazard to life and property in the vicinity. The conclusions of law were:

1. That the order of the Inspector of Buildings directing the tearing down, razing, and removing of the buildings is fair and reasonable.

2. That the relief sought by the property owner to prevent the demolition of the buildings be denied.

3. That the buildings be removed forthwith.

The general rule of the building department is to avoid court action whenever possible. Numerous condemnations at any one time in any one block or ward are also avoided.

In ridding Milwaukee of undesirable housing, the Department of Building Inspection has been free from political influence or interference, and maximum results have been obtained through the coöperation of the citizens.

A summary of the number of buildings razed and the number of families affected by this elimination of undesirable and unsafe housing since 1928 follows:

	1928	1929	1930	1931	1932	1933	1934 to June 1	Total
Buildings razed	400	271	412	406	463	414	277	2643
Families affected by razing	245	160	235	195	176	263	150	1424

The following table shows the success of the building condemnation program in Milwaukee during the first part of 1934 as compared with the same period of 1933.

Buildings Razed.

	1934			1933		
Month	Dwellings	Commercial Buildings	Total	Dwellings	Commercial Buildings	Total
January	5	11	16	5	12	17
February	11	28	39	11	10	21
March	22	37	59	10	9	19
April	26	64	90	10	10	20
May	26	47	73	13	8	21
	90	187	277	49	49	98

On June 1, 1934, there were 122 additional buildings still under condemnation orders issued in 1934, and 93 issued in 1933, which had not yet been razed.

Notes on Arson Investigation.

By Paul T. Wolfe,
Arson Bureau, Los Angeles Fire Department.

The illustration used by one of Europe's most noted police departments in instructing their men to be thorough in every respect, points out that if in only one case out of ten thousand it proves necessary to know whether the murdered man's shoe soles were moist, a careful note of this must be made at the time of the original investigation. Otherwise when this is found to be important weeks later, it will be impossible to go back and establish the fact.

The watchword of competent arson investigation is thoroughness. We try to take into consideration every possibility that may arise in months to come in proving the point in question. Arson is almost invariably a case of circumstantial evidence and every link of that evidence must be so clearly established that there can be no doubt as to the guilt of the individual in the case. No detail may be overlooked or passed by.

While we read a great deal of cases where many gallons of flammable liquids have been used and elaborate timing devices employed, little credit is due an investigator for securing a conviction in such a case. In this type of case the incendiarist leaves a telltale trail that can be followed by any amateur. The difficult cases are those so carefully prepared and executed that little or no evidence remains.

We have called attention to small details as being very important. For instance, it may be found that some plaster has been chipped off the lath of a building to allow the flames to communicate to the wood. In one case small particles of plaster were found under the finger nails of the suspects, a man and a woman, and also in the cuffs of the man's trousers and in the pockets of the woman's smock. With the use of a microscope we were able to identify these particles as being the same as the plaster in the building where the fire occurred. Plaster in different buildings can be distinguished by the difference in the combination of sand making up the plaster. For instance, in 50 grains of sand 10 may be black, 14 red, 14 amber color, and 12 white. There is always a definite ratio for each mixture.

Another example of the value of attention to details was a case handled by our bureau, where holes had been bored up through the supports of the building so that strips of paper saturated with flammable liquid could be twisted into these holes. We sawed out a piece of the timber and made a cut lengthwise through the holes. When these sections were examind under microscope it was observed that a minute burr on the flange of the bit making the hole had left a track each time the bit was rotated in the wood. Our further investigation disclosed that the owner of the building was a carpenter. A full

set of bits was found in his locked tool chest. He claimed that he had never loaned out any of his tools and when the same size bit from his set was used to bore a hole through the same piece of wood and it was examined through a microscope the same peculiar markings were found, which proved beyond a doubt that the holes used in setting the fire were bored by the owner. With this evidence a conviction was secured.

It is sometimes possible to identify excelsior by a burr or peculiar shape of the tool used in making it. If the excelsior used in setting a fire is compared and similar pieces of excelsior found in the possession of the suspected person, this makes valuable evidence.

Candles are the most common timing devices used and a smart incendiarist will devise a method to burn or destroy the wax from the candle. Where we think a candle has been used, we pulverize the wood at this point and wash it with ether. If the pulverized wood is then filtered and the ether allowed to evaporate, if there is any paraffine present, it can be identified.

Naturally candles of all types and sizes are used, from those that will burn forty-five minutes up to those that will burn up to 960 hours. In most cases the arsonist will cut the candle down to the proper burning time to allow him to prove his alibi. For this reason we have found it advisable to examine the pocket knife of the suspect immediately and in many cases with the aid of a microscope we have found candle wax on the knife blade, this wax being invisible to the naked eye. In one case we found on the knife blade, in addition to the wax, fibers from a cardboard box printed in purple ink, which had been made into a candle holder. Evidence like this, of course, ties the individual in with the crime.

Finger prints are of little or no benefit in arson cases as in most cases the occupant of the building is responsible for the fire. Footprints and tire tracks, however, are useful evidence and should be carefully observed and preserved. A method that we use that gives very satisfactory results is to spray the print with shellac cut with about 30% alcohol. We give the print four or five coats and allow five minutes for drying between coats. Then we mix plaster of Paris to a very thin consistency and pour it into the track, agitating it lightly to let out the air bubbles. It is desirable to add a few splints of wood or rope fiber to strengthen the cast. The print is then covered with a box and several hours are allowed for it to dry and harden. The shellac is then washed off with concentrated lye. This method will preserve markings in the tracks that are practically invisible to the naked eye.

Another method that can be used to preserve a track is to scrape off small shavings of paraffine into the track, lightly touching them with a blow torch so that the track will be coated with the paraffine. The track can then be dug up and placed in a box and kept indefinitely.

We always examine the clothing of a suspect very carefully. I remember one case where a fire was started under a house. A small amount of fox tail

grass was growing under the house and this grass had been bleached to almost snow whiteness, due to the fact that little or no sunlight reached it. When the clothing of the owner of the house, who lived two blocks away, was examined particles of this snow-white fox tail grass were found in the cuffs of his trousers, giving us a valuable clue.

While in many cases it is the practice to keep any information that the arson investigator may have away from the suspect, we work on exactly the opposite theory. We have found it an advantage to talk over our case with the accused, placing all the facts before him, pointing out in just what manner he would profit by the fire, all the evidence that was found, and the statements of various persons. This evidence can be presented in court in the form of conversation.

It is perfectly legitimate to trick the suspect in the making of statements. For instance, where two people are suspected it is well to separate them and question them separately, going into detail as to the time of their movements, etc. If a person is lying, this method will usually bring out the truth. It is an advantage to get the suspect's mind away from the subject of the fire and then come back suddenly with other questions. If the ordinary line of questioning is followed he can figure out the time from place to place so that his whereabouts will fit in perfectly.

Experience has taught us that failure to convict in a number of arson cases has been due to making the arrest before the defendant has time to make up a false insurance claim. Such a claim would give us a motive for the fire. For this reason we recommend that an arrest not be made for thirty, sixty or ninety days or until the insurance claim has been made.

Photographs are without a doubt the best method of presenting evidence and should always be marked with the direction from which they are taken as to the points of the compass. Photographs for arson work should be larger than the ordinary police photograph. It is false economy to try to save on photographs. You may fail on a case with three or four pictures, when a dozen would absolutely bring out all the evidence. Photographs are inexpensive, but it costs many hundreds of dollars to carry a case from the lower court to the higher court.

Where gasoline or other flammable liquids are found on the clothing or shoes of the suspect the investigator has a perfect right to seize these articles. We sprinkle these spots with an oil solvent dye, which will dye the spots into the material so that even after the oil has evaporated they will show up plainly for the benefit of the court.

The foregoing are simply some examples of the details and care necessary for successful arson investigation. The investigation of arson cases is the most difficult and most discouraging line of criminal investigaton and the successful arson investigator must have a great deal of tenacity to carry on his work properly.

A Prearranged Plan for Mutual Aid.*

By P. H. Parker,
(Member N.F.P.A.)

Conflagrations and other fires of sufficient magnitude as to require outside aid during the past few years in New England have demonstrated the ease with which motor pumping units and other types of apparatus from a dozen or more communities may be mobilized at any given point within a comparatively short time. Requests for aid have been generously answered by fire departments from whom help has been asked, but this response, at the same time, might have been much more effective had definite plans and preparations been made prior to the emergency.

No city or town can provide a "conflagration size" fire department and when a serious condition arises, effective outside aid must be obtained quickly if the fire is to be confined within a comparatively narrow area. To insure this, as well as to relieve the fire chief of the burden of calling outside aid at a time when his whole attention should be directed to his attack on the fire, a plan for systematic mobilization of fire forces in a given area has been prepared.

This plan, which is to be considered only as of a tentative nature, was prepared as the result of a study made of the methods of calling outside assistance to a large fire in a Massachusetts city in 1933. Such a plan will necessarily be of more value outside of metropolitan areas, within which interconnection of fire alarm systems and concentration of fire stations make the mobilization of fire apparatus relatively automatic. Outside of such areas, installation and maintenance costs make this method of communication less practicable, and help is chiefly summoned by telephone. In these areas, therefore, it is desirable that definite arrangements should be made in advance for summoning the help needed, in order that rapid mobilization be made possible.

Present Conditions.

The fire chief, on his arrival at the scene of the fire, should be in a position to give his entire attention to formulating a plan of attack, and to placing his forces in the most advantageous positions. His knowledge of local conditions and ability to "size up" the fire enable him to estimate what equipment will be required to bring the fire under control. He cannot be expected also to quickly visualize the fire fighting forces within a radius of perhaps twenty-five miles, a territory from which he must call help, not only to assist in the actual fire fighting, but to protect his city by the "covering-in"

*This article first appeared in the Journal of the Associated Municipal Signal Services, June, 1934. Minor revisions have since been made in the original text to broaden its scope.—Ed.

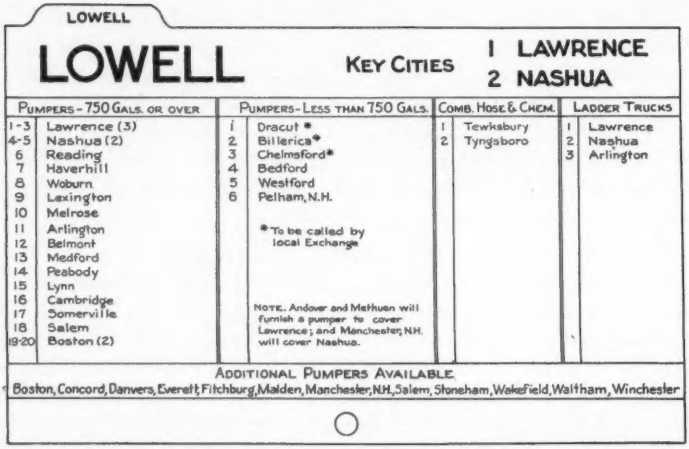
with sufficient apparatus to handle a second fire. He may at once decide that five, ten or fifteen pumpers are required for these duties, but immediately the question arises, where to get them. To intelligently answer this question the chief must be familiar with the number and type of pumpers in the several cities and towns and the time it will take them to reach his city. This is information that no chief can be expected to keep in mind unless there has been prepared in advance a list of communities which may be called, together with the amount and types of apparatus available.

Telephone Exchange Congestion.

Another handicap in calling for outside help is the congestion which always occurs in the telephone exchange at the time of an emergency. This is particularly acute when emergencies occur during a period when business is suspended, as at such times fewer operators are on duty and the telephone service is at its weakest. Such weakness is certain to have some effect when an attempt is made to place a dozen or more emergency *out* calls to obtain help, when a large number of *in* calls from inquisitive or excited citizens are being received. Every one of these *in* calls must be answered by the telephone operators as any one may be a report of another fire or other emergency call. Any one who has attempted to place an *out* call at such a time will appreciate the attendant delay, and telephone officials will confirm the statement that the central office switchboard is ablaze with lights almost before the bell or whistle has ceased to sound its call for the "off-shift" members of the fire department. This condition is greatly aggravated where all fire department signals are audible. When calling parties request the fire department these calls must not only be handled by the exchange, but must be answered by the man in the station who is busy trying to make calls for aid, and often extremely valuable time is lost.

Curiously, a great number of serious fires have occurred on Sundays, holidays or at other times when business establishments are closed. Baltimore, Chelsea, Nashua and Norfolk burned on Sundays; the Fall River fire started after working hours and two serious fires in Lowell, Mass., one on a store half-holiday and the other on a Sunday afternoon, are examples. This is a condition bound to recur, as at such times manufacturing and mercantile buildings are unoccupied.

Even under the most favorable conditions, the calling for assistance has been more or less of a "hit or miss" affair and the chief does not know what apparatus he is to receive or how soon to expect it, and so cannot plan how to utilize the equipment until it arrives. This may prevent the mobilization of pumpers at strategically important points until too late to accomplish desired results. Chiefs in cities and towns which may have been overlooked in the rush of calling aid, upon learning of the seriousness of the fire often proceed to the fire city without equipment and offer aid which is generally quickly



LOWELL

LOWELL — KEY CITIES — 1 LAWRENCE, 2 NASHUA

PUMPERS - 750 GALS. OR OVER		PUMPERS - LESS THAN 750 GALS.		COMB. HOSE & CHEM.		LADDER TRUCKS	
1-3	Lawrence (3)	1	Dracut *	1	Tewksbury	1	Lawrence
4-5	Nashua (2)	2	Billerica*	2	Tyngsboro	2	Nashua
6	Reading	3	Chelmsford*			3	Arlington
7	Haverhill	4	Bedford				
8	Woburn	5	Westford				
9	Lexington	6	Pelham, N.H.				
10	Melrose						
11	Arlington		*To be called by local Exchange				
12	Belmont						
13	Medford						
14	Peabody						
15	Lynn						
16	Cambridge		NOTE. Andover and Methuen will furnish a pumper to cover Lawrence; and Manchester, NH. will cover Nashua.				
17	Somerville						
18	Salem						
19-20	Boston (2)						

ADDITIONAL PUMPERS AVAILABLE.

Boston, Concord, Danvers, Everett, Fitchburg, Malden, Manchester, NH, Salem, Stoneham, Wakefield, Waltham, Winchester

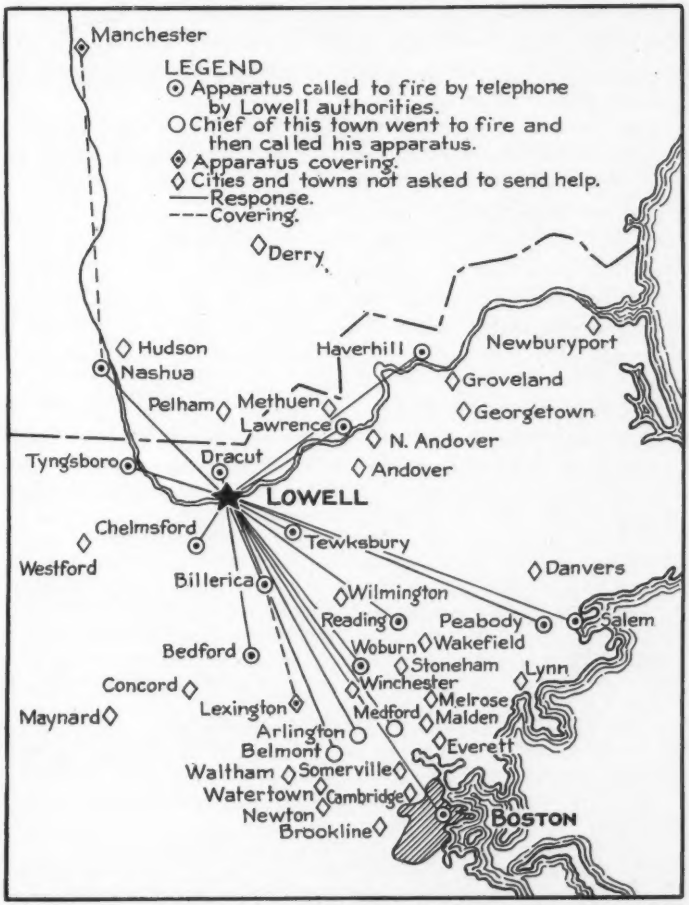
Figure 1. Typical mutual aid plan card for Lowell, Mass., showing outside aid available to be called in event of fire of conflagration proportions. If such a fire occurred, the Lowell chief would communicate by telephone with fire department headquarters in Lawrence (the first "key" city), from whence requests for the apparatus required would be sent out to communities listed on the card in the order named.

accepted. This, it can be readily seen, causes unnecessary delay at a time when minutes count.

Proposed Mutual Aid Plan.

Having, thus, a fairly accurate picture of present conditions the following mutual aid plan is suggested to provide for similar emergencies in the future. Under this plan a card is prepared for each city or town included in the mutual aid agreement, listing the equipment available in the neighboring communities in the order in which they are to be called in an emergency. Each city or town is furnished with a complete set of cards; i.e., a card for each municipality of the group. This card (see Figure 1) shows the name of the cities, two "key" cities, and a list of available apparatus to aid in extinguishing a large fire and to protect the city by "covering-in."

The operation of the plan is simple. In the event of a serious fire in a particular community in the group, the chief of the fire department concerned will determine the quantity and type of apparatus he requires and have an emergency call put in to the first "key" city listed on his card. In every case this "key" city will be the nearest city which is provided with good trunk service to its local telephone exchange. The chief's messenger in the fire city will simply inform the "key" city fire department of the fire and state the number of pieces and types of apparatus required. The telephone service in the "key" city being normal it is a simple matter to call the departments



Map showing response and "coverng-in" at fire in Lowell, Mass., June 1933.

listed on the card for the fire city. Two "key" cities are listed as a precaution so that should emergency conditions also exist in the first "key" city the calls would be sent out from the second city listed. Suburban communities, adjacent to the conflagration city, may be called through the local telephone exchange and so might not be listed on this card. It is recommended that such communities arrange for a local mutual aid system and that these departments be connected by fire alarm telegraph.

It will be noted that the sample card calls for the dispatch of apparatus, in every case, from the "key" city. The man in charge of the fire depart-

ment switchboard in that city will immediately start such apparatus on the way to the fire city and will then proceed to put in sufficient emergency telephone calls to cities and towns, as listed on the card, to obtain the balance of the number of units called for.

As an illustration of the practical operation of a plan of this sort there is presented a map showing the actual response of apparatus to the fire of June 25, 1933, in Lowell, Massachusetts. The card shown in Figure 1 indicates how the suggested plan might be worked out for future conflagrations in this city. Nothing said in the foregoing text should be construed as criticism of the handling of this particular fire. Any errors or omission in calling for assistance which may seem apparent in the example chosen have applied equally to serious fires in other cities, and are to be expected when arrangements to provide for such emergencies have not been worked out in advance.

The advantages of this plan are as follows:

1. Only one call for aid is made from the fire city. By thus reducing the many calls to one, the fire department telephone line or switchboard is kept free to permit the answering of calls for other fires or for the transaction of department business.

2. As in the case of Anderson, Indiana, in January 1934, the telephone exchange may be burned early in the fire, thus cutting off service and preventing the completion of a number of calls. This is overcome by placing a single call only.

3. All calls, other than the initial one, are made from a city where there is no telephone traffic congestion and where the fire department operator is not working under a severe nervous strain as is the one in the fire city.

4. The chief is assured of such apparatus as he needs being promptly dispatched from the nearest points. In the case of the Lowell fire, help was called from a distance of 25 miles or more, while there were a considerable number of units available at a less distance.

5. In some cases in the past there has been delay on the part of the fire department called for assistance by reason of the officer in charge at headquarters being obliged to locate a commissioner or the chief and obtain permission to dispatch apparatus. If assignments had been arranged for previously and card prepared accordingly, this delay would not have occurred.

6. No area from which apparatus is drawn should be left without sufficient protection in case of a fire breaking out in it and consideration has been given to this in the preparation of the suggested mutual aid card. For this reason, as it will be noted, certain cities and towns are not called upon to dispatch apparatus to the fire city, these forces being held, rather, to protect the area from which other apparatus has been drawn.

7. The cost of preparing the cards, when divided among the cities and towns subscribing to the plan, will be small.

The Ignition Temperatures of Solid Materials.*

By Clement R. Brown.

As a measure of ignitibility, the ignition temperature is considered of importance in the estimation of the fire hazard of a material. Determinations made in previous investigations, however, are characterized by wide variations in results for similar materials, owing in part to a lack of understanding of the effects of the various factors involved in the experimental procedures used. This paper presents a study of three of the important factors which affect the results of determinations on solid materials, namely, rate of air flow, size of specimen, and rate of heating.

The method used was selected for its adaptability to such solids as wood, paper, vegetable fibers, etc., and employs a unique criterion for ignition temperature which permits a closer approach to the fundamental definition of this characteristic than any used previously. In addition to results on the materials used in the principal study, filter paper, jute fiber and western red cedar, data are given for determinations on fourteen other materials.

Previous Investigations.

An intensive study of the literature on the ignition temperatures of solid materials has indicated that the diversity of results is due to lack of agreement on definitions, variations in experimental procedures, and physical and chemical differences in apparently similar materials. The various definitions which have been given can be divided into several classes, most of which are unsatisfactory. From a practical standpoint, the statement that the ignition temperature is the lowest temperature at which "self-heating" leading to visible or active combustion begins, appears to be quite adequate. Considering the fundamental phenomena of ignition, however, and assuming conditions favorable to the completion of the ignition process, the ignition temperature can be defined as the temperature in the combustible at which the rate of heat developed by the reactions inducing ignition just exceeds the rate at which heat is dissipated by all causes, under the given conditions.

There are three principal classes of methods which have been used in determinations on solid materials. The *constant temperature* methods are characterized by the fact that the external heating medium is maintained at various relatively constant temperatures at which portions of the specimen are introduced. The occurrence of ignition is noted by such phenomena as glow, flame, rapid heating, etc., after a period of time called the "lag," and

*Extracted from a dissertation by the author "The Determination of the Ignition Temperatures of Solid Materials," published by The Catholic University of America, Washington, D. C., June, 1934, copies of which can be obtained from the University.

by trial and error the lowest temperature sufficient to cause ignition is determined. Only a few determinations have been made by the *compensated temperature rise* or "adiabatic" method, in which the heating medium is first maintained constant at some temperature and if the specimen begins to heat spontaneously above this temperature, the latter is then increased so as to "follow" the temperature in the specimen until ignition becomes evident. Except for many determinations on explosives, the third, or *rising temperature,* class of methods has been used most extensively in determinations on solid materials. In this type, the specimen is heated by a continuous or intermittent rise in temperature of the heating medium, and in many cases some form of vertical tube is used in which either the specimen is suspended freely or in which it is packed as a layer of finely divided material. In both cases, air* is generally either passed over the surface of the specimen or is forced through it, and temperatures are measured in the specimen and/or the heating medium at frequent intervals. It is to be noted that variations in such details as the means of introducing and heating the specimen and the manner in which air is supplied to the ignition chamber permit further classification of methods.

Factors Involved.

Among those factors inherent in the experimental procedure, the criterion of ignition temperature used by the investigator is perhaps the most important. By criterion is meant the particular event or observation during the experiment, which has been chosen as evidence that the ignition temperature has been obtained. In the constant temperature tests, it may be the lowest temperature in the heating medium which will just produce glow, flame, explosion, etc., while in the rising temperature tests, it may be some point in the temperature-time curve of the specimen, such as that at which the curve turns upward, or begins to rise rapidly, or crosses the heating curve for the furnace, etc. In all, over thirty different criteria have been used in determinations on solids which indicates one reason for the diversity of results.

In addition to the type of method and criterion of ignition temperature, the results of determinations are affected to an appreciable degree by a number of experimental conditions, including the size of specimen, the nature of the ignition atmosphere, the rate of air flow, the time of exposure, or lag,† in constant temperature tests and the rate of heating in rising temperature

*In using the term air, it should be noted that oxygen as well as air, and even other gases, have been used as the ignition atmosphere.

†The term "lag" is used to indicate the elapsed time between the introduction of the specimen and the appearance of some visible evidence of ignition, such as flame. As the furnace temperature is decreased (in different trials), the lag increases until finally ignition is no longer obtained. The lowest temperature at which ignition is obtained in these constant temperature tests is termed the ignition temperature. The lag is a matter of seconds in the case of gases and liquids, but extends into minutes in the case of solids.

tests. With regard to the ignition atmosphere, the results of different investigators seem to agree that oxygen gives lower results than air even when the rate of flow of the latter was increased to partly compensate for the lower concentration of oxygen in air. Moisture in the ignition atmosphere appears to be a negligible factor, if any. Also, there is agreement that the lag increases as the container temperature decreases, in constant temperature tests, particularly as the ignition temperature is approached. While a number of studies have been made on each of the other three factors mentioned, the ranges covered were generally inadequate to establish definite relations, particularly for all three in the case of any given material. Consequently, it has been one of the purposes of the present investigation to study the effect of these three factors, rate of air flow, size of specimen and rate of heating on the results with three representative solids.

There are also factors which are inherent in the combustible itself, such as fineness, moisture content, etc., which often affect the results to such an extent that it is difficult to compare data on the same substances from different sources. While important, these factors were deemed outside the scope of the present study.

The effect of long continued exposures to temperatures above normal has likewise been considered outside the scope of the present study. After heating at temperatures above normal, but not too high, the nature of the material may change so that its ignition temperature is lower than that of the original product. This is due to the fact that the nature of the material itself is changed, and is not related in any way to the method of test.

Experimental Method.

A rising temperature type of method was selected for these experiments because it is better adapted to solid materials, it apparently gives lower results than the constant temperature type, and it more nearly represents practical conditions from the standpoint of fire hazard. As shown in Figure 1, the specimen, which was about 6.5 cm. long, was suspended in a Pyrex jar by means of a porcelain insulation tube which protected the leads of the thermocouple inserted into the specimen. The jar, which was 6.4 cm. in diameter and 12.3 cm. high, was located in the central portion of the vertical tube of an electric furnace, which was well insulated and controlled by a large rheostat. The air used was at normal atmospheric pressure and within the normal range of moisture content, as these conditions are most frequently met in the handling and storage of combustible materials. The compressed air of the laboratory was first passed through a reducing valve, then through a flow-meter which indicated the rate of flow, and thence to the copper coil inserted into the Pyrex jar. The coil served to preheat the air which entered the jar at the bottom and flowed upward after passing through a thin per-

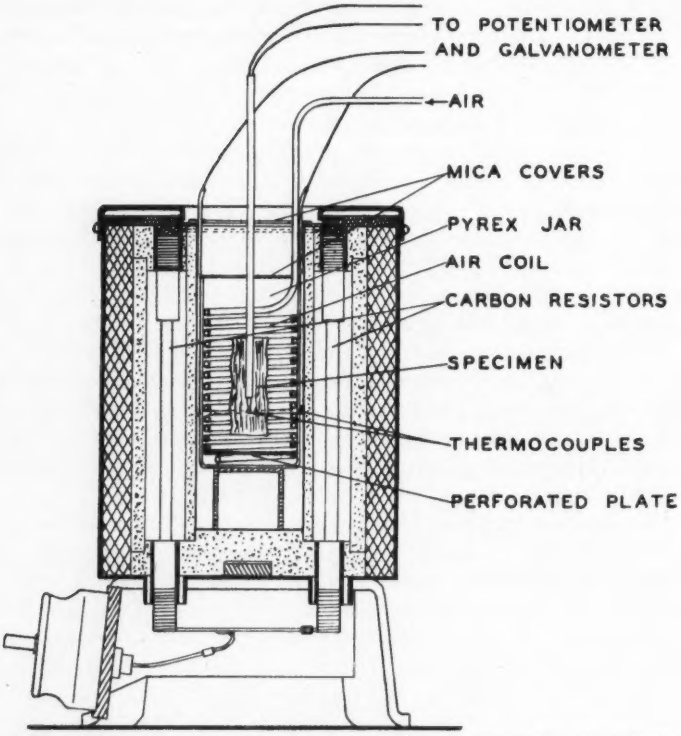


Figure 1. Section of furnace, showing location of Pyrex jar, air coil, thermocouples and specimen.

forated mica plate located below the specimen. As noted previously, a thermocouple was used to measure temperatures in the specimen, while a second thermocouple placed between the jar and the furnace tube served to measure the temperature in the furnace. The couples were connected, through switches, to a potentiometer, and were also connected to a galvanometer which indicated the difference in temperature between them.

In making a determination, the specimen was first weighed and then wrapped tightly in position on the porcelain tube by means of asbestos string. The specimen and tube were located centrally in the jar, which was then covered, the air flow adjusted to the desired rate and the current turned on, with the rheostat set at a predetermined position. When the temperature approached the region where ignition was expected, frequent readings were taken on each thermocouple and particularly of the galvanometer, which measured the difference. As soon as the appearance of smoke and a rapid rise

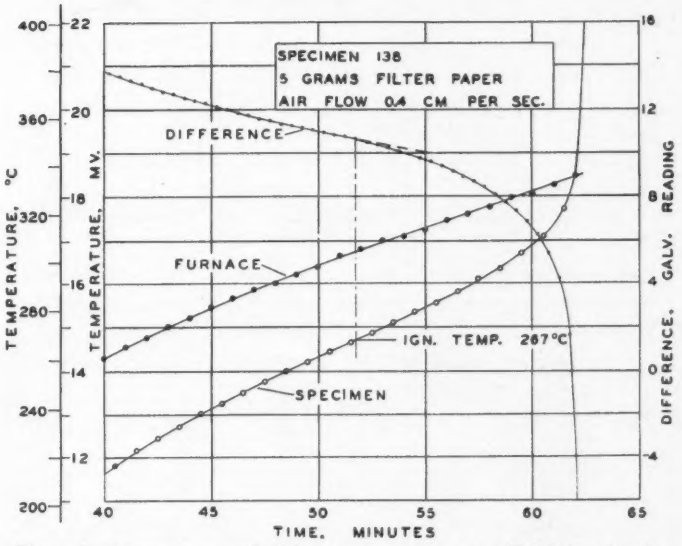


Figure 2. Temperature and difference curves for a typical determination of ignition temperature.

in the specimen temperature indicated that active combustion was taking place, the specimen was removed, and if not already glowing or flaming, it could generally be readily blown into visible combustion.

The temperature and difference readings were plotted against time, the former in millivolts and the latter in scale readings. Figure 2 shows the plotted curves for a typical run and also illustrates the use of the difference curve in the criterion of ignition temperature selected for these experiments. It will be observed that the furnace heating curve is concave downward, and consequently the temperature curve for the specimen is also concave downward as long as self-heating does not occur. The difference curve is concave upward and tends to become parallel to the time axis. When the heat produced by combustion in the specimen exceeds that lost to the surroundings, however, its temperature rises faster than it would due to the external heating alone, and the specimen temperature curve approaches the furnace heating curve at an increasing rate, soon crossing it. At the point where self-heating begins, that is, the ignition temperature, the difference curve changes definitely from concave upward to concave downward, thus furnishing a reliable means of indicating this temperature, as shown in Figure 2. The rates of heating (or temperature rise) were determined by drawing tangents to the heating curves just below the ignition temperature.

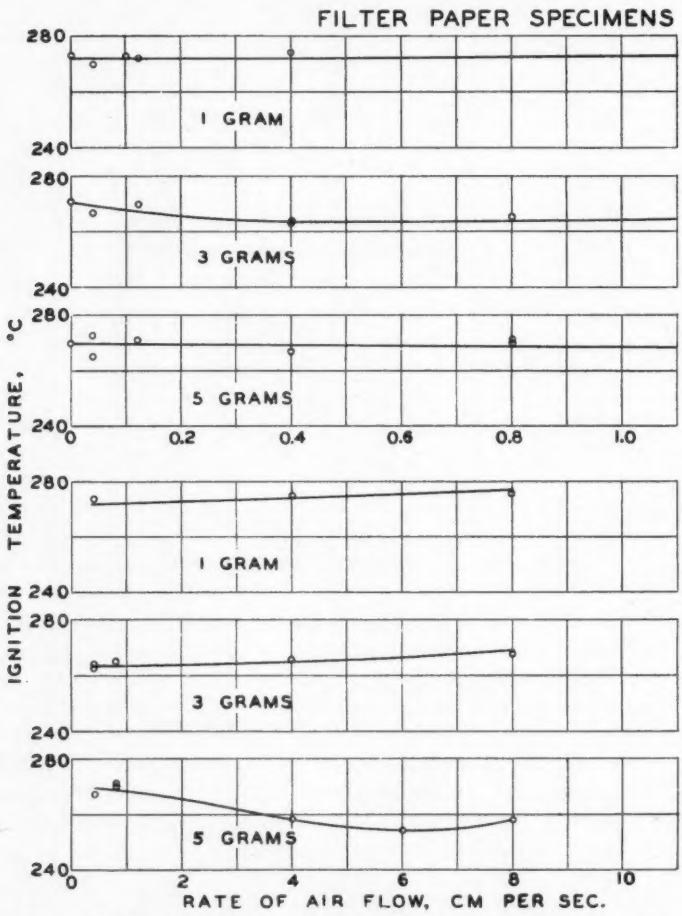


Figure 3. Relation between ignition temperature and rate of air flow for filter paper specimens.

Experimental Results.

The effects of the rate of air flow and the size of specimen were studied first. By using three sizes of capillary tubes in the flow-meter it was possible to make determinations at relatively very low rates of air flow and still cover a wide range without sacrificing accuracy. This study was made on 1, 3 and 5-gram specimens and check tests were made in many cases. The results of these tests on filter paper, jute fiber and western red cedar are presented graphically in Figures 3, 4 and 5, respectively. The rates of air flow have

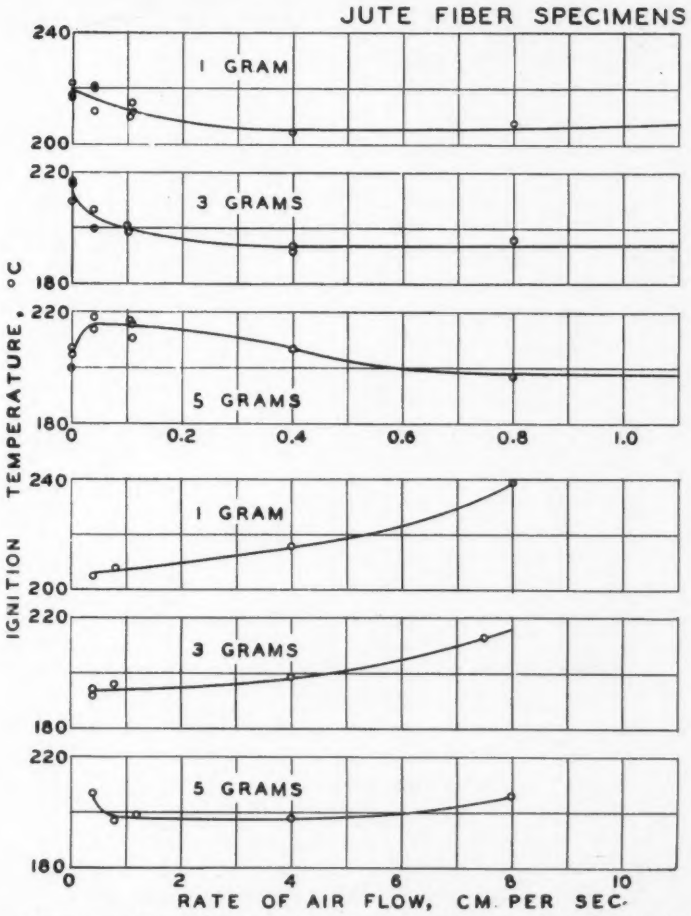


Figure 4. Relation between ignition temperature and rate of air flow for jute fiber specimens.

been given in terms of linear rate up through the tube, rather than volume rate, as the first figure is more valuable in comparing data from different sources. It is also to be observed that because of the wide range covered, the results over the range from 0 to 1.0 cm. per second are given in the upper half of each figure, while those for the range from 0.4 to 8 cm. per second are given in the lower half.

These curves show that the ignition temperature passes through a minimum as the rate of air flow increases, but the position of this minimum varies

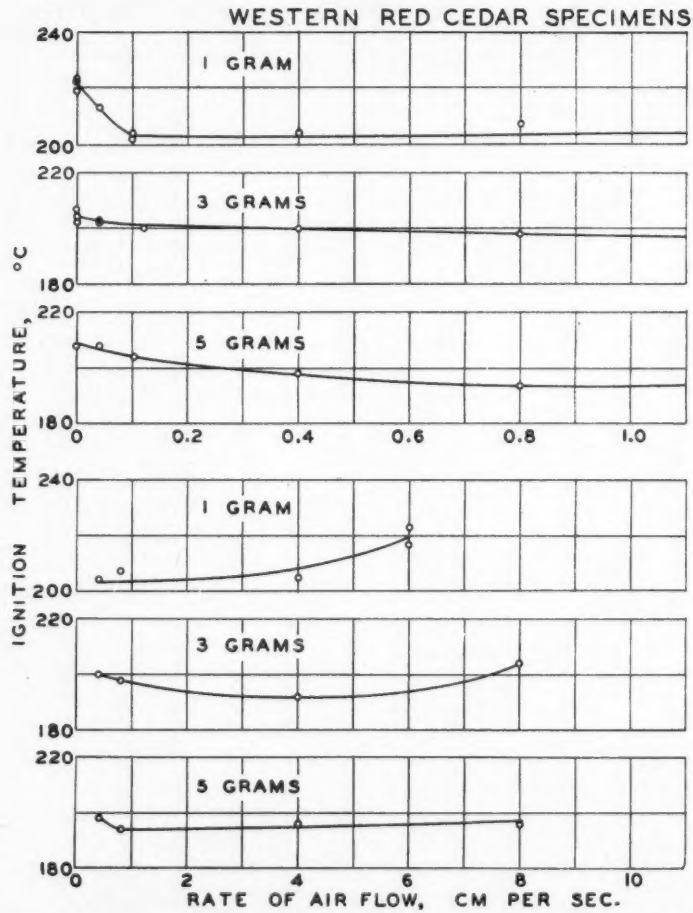


Figure 5. Relation between ignition temperature and rate of air flow for western red cedar specimens.

with the size of the specimen as well as the nature of the material. The minima tend to occur at higher rates of flow as the size of specimen increases. As a consequence of this shift in the location of the minimum, the nature of the relation between ignition temperature and size of specimen changes as the rate of air flow varies. This can be shown by plotting points taken from the curves for the respective sizes of specimen at a number of selected rates of air flow. Nevertheless, the lowest value for all determinations on 3-gram specimens is lower than the minimum for 5-gram specimens in the

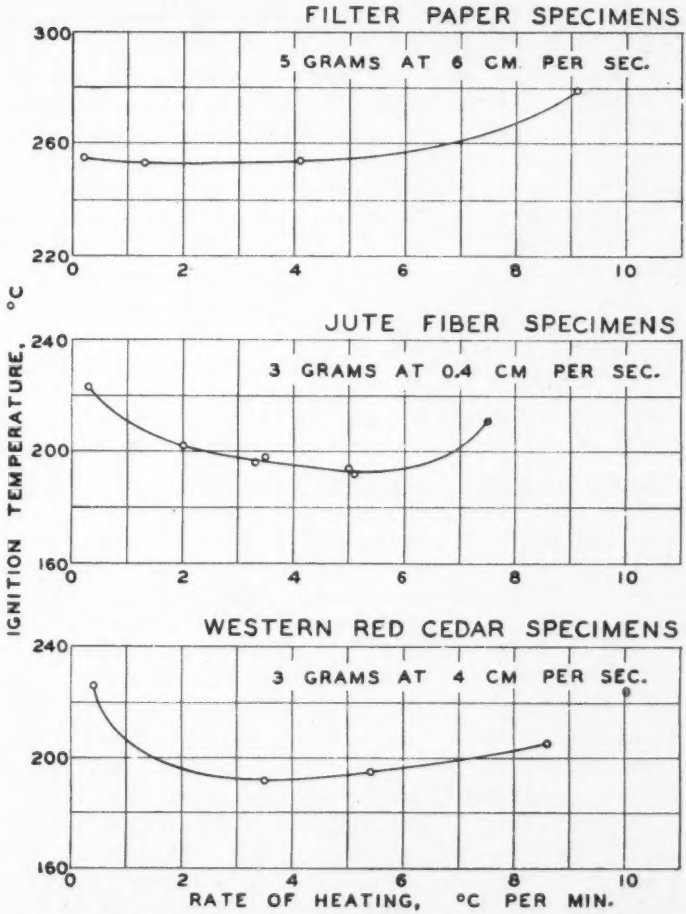


Figure 6. Relation between ignition temperature and rate of heating.

case of jute and cedar, which might be taken to indicate that the relation between ignition temperature and size of specimen also passes through a minimum. On the other hand, the results on filter paper would not lead to such a conclusion and for this material, at least, further tests (requiring a larger furnace) would seem to be necessary.

For the rate of heating series, all of the determinations on each material were made with the size of specimen and at the rate of air flow which had given the lowest result for that material in the previous series. The curves

for all three materials are plotted in Figure 6 and pass through minima which do not occur exactly at the same rate of temperature rise in the specimen. It is to be noted that for an appreciable range in the vicinity of the minimum the ignition temperature varies but little with rate of heating and consequently the results of the tests in the previous series were considered satisfactory if the rate of heating fell within this range. Otherwise the test was repeated. The fact that the ignition temperature tends to increase as the rate of heating becomes very low adds weight to the contention that the rising temperature methods give lower results than the constant temperature methods, other factors being equal. This is seen to be logical when it is considered that the rising temperature of the furnace helps to support the additional rise in temperature in the specimen due to self-heating in the latter when ignition occurs. This is not true in the case of tests made at constant furnace temperatures.

Having found the respective optimum rate of air flow, rate of heating, and size of specimen (in the range covered) for obtaining the minimum igni-

Ignition Temperatures for Various Materials at Given Conditions.

Material	Rate of Temperature Rise Furn. °C per min.	Spec. °C per min.	Ignition Temperature °C	°F
Results on 5 Gram Specimens at 6 cm. per Sec.				
Filter paper	3.6	4.1	254	489
Cellophane	3.2	3.6	242	468
Cellulose paper	3.1	4.2	239	462
Cellulose acetate*	2.5	3.6	314	597
Leather	2.2	3.6	212	414
Magnesium	0.9	1.0	507	945
Newsprint paper	2.8	3.2	184	363
Results on 3 Gram Specimens at 4 cm. per Sec.				
Western red cedar	3.2	3.5	192	378
White pine	3.0	3.0	208	406
Longleaf pine	3.6	4.2	220	428
White oak	3.8	4.4	210	410
Paper birch	4.0	4.6	204	399
Results on 3 Gram Specimens at 0.4 cm. per Sec.				
Jute fiber	4.2	5.0	193	379
Absorbent cotton	3.8	4.9	228	442
Oiled viscose rayon**	3.4	3.9	248	478
Unoiled viscose rayon	3.5	4.6	234	453
Tobacco	2.9	3.5	172	342
Hay	3.4	4.4	172	342

*Endothermic (heat absorbing) reactions noted at about 210° and 270° C.

**An exothermic (heat producing) reaction noted at about 150° C., due to spontaneous heating of the oil, but which was not of sufficient intensity to ignite the rayon under the test conditions.

tion temperatures of filter paper, jute fiber and western red cedar shavings, these conditions were applied in determinations on a number of other materials which were grouped into three classes, according to their similarity to the first three. This procedure was based on the tentative assumption that the minimum ignition temperatures of materials of similar physical structure should be reached under similar experimental conditions, which has been made in lieu of complete studies in order at least to approximate their minimum ignition points. The results of these determinations are presented in the accompanying table. These data are the first available for many of the materials and those for the others are lower to a varying extent than previous figures to be found in the literature. The latter fact may be taken as evidence that the procedure used permits a closer approach to the minimum ignition temperatures of solid materials under conditions likely to be met in practice than previous methods.

Summary.

The three principal causes of the diversity of results in determinations of the ignition temperatures of materials are lack of agreement on definition, variations in experimental methods used, and differences in the materials themselves. Among the important factors inherent in the experimental procedure which affect the results with solid combustibles, the rate of air flow, size of specimen, and rate of heating have previously not been studied sufficiently to establish definitely the relations between them and ignition temperature. A rising temperature method for determinations on solid materials has been described in which the difference between the furnace and specimen temperatures is employed in the criterion of ignition temperature. This method was used in the study of the above three factors in which it was found that as either the rate of air flow or rate of heating is increased, the ignition temperature passes through a minimum. This was also apparently true for the size of specimen in the case of jute fiber and western red cedar, but in the case of filter paper, the range covered was probably insufficient to justify a conclusion. The optimum conditions found in these studies were used in determinations of the minimum ignition temperatures of a number of solid materials and the data presented are deemed of value in the estimation of their fire hazard.

The Hakodate, Japan, Conflagration.

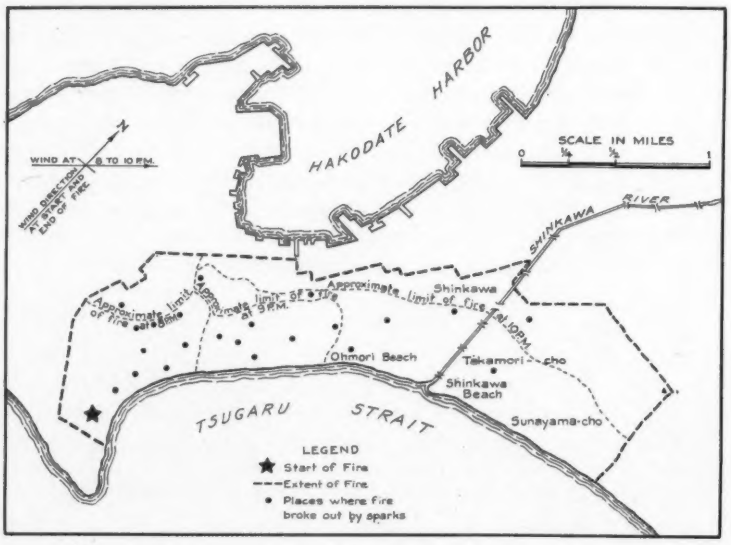
By Teruichi Nohmi,
(Member N.F.P.A.)

On March 21, 1934, the city of Hakodate, Japan, was swept by a conflagration which destroyed approximately half the city and caused the loss of more than two thousand lives. The number of buildings destroyed was 11,102 and the loss was estimated at 123,908,327 yen (approximately $61,954,083 at par).

Hakodate is a seaport located at the neck of a small peninsula on the southeast coast of the island of Yezo. Its area is about twelve square miles and it had a population of 216,000 people. The city is a distributing center for the agricultural and marine products of the province of Hokkaido and is the southern terminal of the railway which runs the length of the island.

Conflagrations are not unusual in this city, there having been twenty-two fires involving more than one hundred buildings each during the past fifty-four years. The greatest of these occurred in 1907 when 8997 buildings were destroyed, and the next largest was in 1921 when 2041 houses were burned. There had been no serious fires since 1921.

Within the fire limits which embraced the center of the city all buildings facing to the road were wooden framed concrete, reinforced concrete, or brick.



A street in the business section of Hakodate before the fire. The fire-resistive building in the foreground withstood the conflagration, but its contents were burned.

In other parts of the city most of the buildings, except public buildings or Government property, were of frame construction, mostly two stories in height. Earth interior walls or partitions were not employed as in other parts of the country. Roofs were principally of corrugated iron sheets, which were thought to best withstand the cold climatic conditions.

Streets ranged in width from about 130 feet, in the center of the city, to about 13 feet in the outskirts. The streets were laid out according to commercial and fire prevention requirements.

Fire Fighting Facilities.

The Hakodate Fire Brigade was organized in 1897 and was reorganized and extended after each successive conflagration. At the time of this fire its personnel consisted of a chief, 148 regular firemen and 160 reserve firemen. The equipment consisted of ten gasoline driven fire engines, eight hose trucks, two steam fire engines and two other pieces of apparatus.

Water for fire fighting was supplied by the city water works. There were 772 hydrants on the water system, from which an average pressure of 70 lbs. was obtainable, with a maximum pressure of 120 lbs. available in certain localities. There were also 60 wells connected with the river and 45 reservoirs connected with water mains, especially designed for fire brigade use.

There were 175 street fire alarm boxes and 4590 public telephones from which notification of fires might be sent and there was a watch tower at fire headquarters from which a look-out was kept for fires.

View of Hakodate ruins following conflagration of March 21, 1934.

There was no fire station in the immediate vicinity where the fire started and it is reported that the water supply in this part of the city was inadequate.

Weather Conditions.

Weather conditions on March 21 were abnormal. A heavy rain, later changing to snow, began to fall at 2 P.M., accompanied by a gradually increasing southwest wind which reached a velocity of more than 60 miles per hour by six o'clock, at which time several whirlwinds occurred in various parts of the city. Signboards were broken off, chimneys were blown down and many roofs were blown away, both before and after the fire started.

At 5:50 P.M. short circuits in the city lighting system (wires were all overhead) were reported from six different parts of the city. The resultant fires were extinguished by the fire brigade, who responded to alarms from street boxes and by telephone.

At 6:50 P.M. weather conditions became so bad that all electric current was shut off, plunging the city into darkness. It was just at this time that the fire broke out.

Story of the Fire.

The fire had its origin on the second floor of a two-story wooden dwelling occupied by a Shinto priest in the southeastern part of the city. It is supposed to have been caused by burning embers from an open fireplace, which was exposed when the roof of the house was blown off by the wind. This section of the city is in a low place and the fire was first observed from the fire

tower at fire brigade headquarters more than a mile away, although there were street fire alarm boxes installed in the immediate vicinity. Three engines and three hose trucks were dispatched to the scene of the fire as promptly as possible. Some delay was experienced, however, due to the fact that most of the men and equipment of the brigade were engaged at fires caused by the short circuiting of electric wires in various other parts of the city.

Most of the houses in the vicinity were old and of wooden construction and the fire once under way had ample material to feed upon. Three houses were well involved when the first fire companies arrived, and sparks and brands were being carried by the high wind to start fires in other places. The brigade did its utmost, but the fire was soon beyond all human control. It spread so rapidly that within two hours it had reached a point approximately two miles distant.

The fire covered an area of approximately five square miles, completely destroying all buildings on twenty-two streets and practically destroying those on seventeen others. The total number of structures destroyed was 11,102, including 18 schools, 48 hospitals, 10 public buildings, 10 theatres, 19 shrines or temples, 6 newspaper offices and 3 banks. Approximately 100,000 people were rendered homeless.

The loss by the fire amounted to 123,908,327 yen, equal at par to approximately $61,954,083 in U. S. dollars.

Loss of Life.

The total loss of life as reported on April 17, 1934, was 2018. The number of injured was reported at 2318, of whom 70 later died. Because of the direction of the wind at the start of the fire many people made their escape to Ohmori Beach (see diagram), where they were trapped when the wind suddenly shifted toward the west. About 550 persons were burned, drowned or frozen when the fire overtook them at this point.

The greatest loss of life occurred at Shinkawa when the three bridges which spanned the Shinkawa River burned or broke under the weight of the panic-stricken throngs. This cut off all escape to the north and 600 persons burned to death in this area. Severe loss of life also occurred in the section of the city to the north of the Shinkawa River. One hundred and fifty were burned at Takamori-cho, at Sunayama-cho some 400 persons who could not pass the mountain were all burned to death and at Shinkawa Beach 120 were burned, drowned or frozen to death.

At other points about the city approximately 100 others were burned to death and many were injured. Some of the injuries were due to direct contact with the fire, others due to efforts to escape and many from flying débris hurled through the air by the high wind.

Spring Perch Company Fire.

Report by Eastern Underwriters Inspection Bureau,
(Member N.F.P.A.)

On May 23, 1934, the plant of the Spring Perch Company, manufacturers of automobile springs, in Lakawanna, N. Y., was severely damaged by fire. The fire is of interest on account of (1) the fuel oil and tempering oil hazards from which it developed; (2) the influence of certain peculiarities in construction, particularly the roof covering; and (3) the fact that the property was uninsured due to the belief of the owners that the construction was sufficiently non-combustible to render it safe against appreciable fire damage.

Description of Plant and Occupancy.

The plant consisted of two adjoining buildings. The warehouse, not seriously damaged by the fire, was 254 x 60 feet in size and of metal clad on exposed steel frame construction. The factory building, in which the fire occurred, was 250 x 165 feet in size, mainly one story high, of light steel construction, with a roof deck of channeled steel sheets welded to expanded steel joists and covered by a combustible roof insulation of ½-inch cottonwood fiber insulating board cemented on by asphalt and covered by three layers of rag felt roofing mopped on with hot asphalt.

The principal product of the plant was steel leaf springs for automobiles, manufactured by bending and heat treating operations, involving the use of fuel oil-fired furnaces, oil-quenching tanks and forming presses operated by a "hydraulic" oil system under 1000 lbs. pressure. The burners of the oil-fired heat treating furnaces as well as lesser furnaces were supplied by fuel oil under about 40-50 lbs. pressure and at about 120° F. temperature, from a slightly detached outside above-ground tank, through a pump, steam preheater and a 2-inch overhead circulating pipe and return line with relief valve. Small pipe connections to the burners were taken from down loops of the supply line. A heavy oil having a flash point of 190-220° F. was used.

The plant was operating at about 50-60 per cent capacity, with about 125 employees. The administration with respect to cleanliness, involving rags, oily deposits, etc., is said to have been rather lax.

Story of the Fire.

A small fitting on the supply line to a small furnace at one end of the manufacturing building was broken out on the supply side of the branch control valve by a factory truck. The oil discharged in front of and/or on the furnace and took fire. There was no automatic shut-off valve, but the master mechanic claims to have shut off the oil pump promptly.

Interior of Spring Perch Co. plant after the fire. Note fallen roof and damage to structural members.

The employees, more or less accustomed to small fires, apparently gave this fire scant attention at first. The fire in the oil on the earth or concrete floor was first extinguished by the use of three or four 2½-gallon soda-acid extinguishers and a 40-gallon soda-acid chemical engine. Following this the master mechanic claims to have stopped the flow of oil from the pipe by holding his finger over the leak. In the meantime smouldering wooden gratings used by the men to stand on, or the hot furnace, rekindled the fire in a pool of oil about 20 x 20 feet in size. With fire extinguishers exhausted, the employees were forced to evacuate this section and finally the building.

While there was a minimum of combustible material in the plant, other than the oil, the fire appears to have spread practically the entire length of the building in the escaped oil and in the accumulations of oil floating on the water in the longitudinal trench carrying the cooling pipes of the quenching oil system. While the fire involved the quenching oil tanks and there appear to have been breaks in the high pressure hydraulic oil pipes, the area of most severe damage to the building indicates that the oil fire was most severe along the lines of the trench where escaping oil would naturally accumulate.

The heat from the oil fire caused serious deflections of the steel columns, trusses and joists supporting the roof, and the melting of the asphaltic content of the combustible roof covering. While the fire in the oil was of sufficient intensity and duration to cause damage to the steel structure and heavily loaded roof system, the presence of the fiber board and felt roof covering made possible a sustained fire over the entire roof area. This covering was practi-

Spring Perch Company building after the fire. Note tank car, above-ground fuel oil tank and quenching oil tank (partly buried) in right background. The first efforts of the firemen were directed to preventing the spread of fire to these tanks. The distortion of the roof members is clearly shown.

cally destroyed over the entire roof, leaving the steel sheets of the roof deck largely in place, except in the central area over the trench system.

Fire Fighting.

There was some delay in giving the outside fire alarm, there being no fire alarm box immediately at the plant. The alarm was telephoned to the plant of the Bethlehem Steel Co. one mile distant, from which a private fire brigade responded. The public fire department received a telephone alarm a moment later.

When the fire department arrived, flame and heavy smoke filled the building and the heat was being blown by the wind in such a way as to spread the fire in the direction of the steel warehouse adjoining. Some delay in checking the fire was caused by the presence of a high wire fence and by the use of the first streams to cool the oil storage tanks and the tank car near the building. In all, six or seven streams were used.

While the quenching oil tanks took fire, the oil fire seems to have been concentrated in the vicinity of the pipe trench and its severity does not seem to have been sustained more than thirty minutes. There was, however, a sustained fire lasting over two hours, apparently largely due to the burning of the combustible roof covering.

Damage.

About 15 per cent of the steel roof structure of the factory building fell in completely. About 25 per cent or more was deflected seriously. The replacement or major repair to 70 per cent of the building appears to be necessary. Windows and most of the steel sash comprising the walls were destroyed. While the fire attacked the walls and roof of the skeleton steel warehouse building adjoining the factory building, the damage was not extensive. Machinery and electrical equipment were heavily damaged. The total loss has been estimated in the vicinity of $90,000 to $100,000.

Lessons From Some Recent Dust Explosions.

By David J. Price, Hylton R. Brown, Paul W. Edwards, and Richard L. Hanson.*

This review of explosions which have occurred during the first seven months of 1934, prepared under the direction of the officers of the Committee on Dust Explosion Hazards of the National Fire Protection Association, furnishes conclusive proof of the practical effectiveness of measures to prevent and control dust explosions, which have been developed by the committee since its organization in 1922. Through the regulations which the committee has prepared, in co-operation with the industries concerned, the results of the technical research of the United States Department of Agriculture have been translated into actual practice. In many of the explosions covered in this review it is believed that both the extent of property damage and life loss were reduced on account of the compliance with the recommendations of the committee, especially in respect to the provision of adequate venting area and proper maintenance and general upkeep of the property.

The Chemical Engineering Division of the Bureau of Chemistry and Soils, U. S. Department of Agriculture, with the coöperation of the various plant managements and insurance inspection organizations concerned, has investigated thirteen dust explosions that have occurred in industrial plants in the first seven months of 1934 as follows:

JANUARY 24, 1934. BUFFALO, N. Y. Explosion of malt dust at Kreiner Malting Plant, resulting in the death of one fireman and a spectator, injury to fourteen other firemen and property damage amounting to $79,000.

MARCH 9, 1934. CLEVELAND, OHIO. Explosion of wood dust in a chair manufacturing plant. One workman killed, four others injured. Property loss, $800.

MARCH 13, 1934. WICHITA FALLS, TEX. Explosion of white corn dust in mill and elevator plant. One workman killed, four others injured. Property and stock loss, $192,000.

APRIL 20, 1934. AMARILLO, TEX. Wheat dust explosion in country elevator, with resultant property loss of $75,000. Three injured.

APRIL 26, 1934. RIVERDALE, ILL. Explosion of feed dust at Arcady Farms Milling Company plant, resulting in approximately $300,000 loss.

MAY 8, 1934. ST. LOUIS, MO. Explosion of yellow corn dust in terminal grain elevator. Seven killed and eight injured. Property and stock loss, $125,000.

*Dr. David J. Price (Member N.F.P.A.), Chairman of the N.F.P.A. Committee on Dust Explosion Hazards, is Principal Engineer in Charge of the Chemical Engineering Division, Bureau of Chemistry and Soils, United States Department of Agriculture. Mr. Hylton R. Brown, Secretary of the N.F.P.A. Committee on Dust Explosion Hazards, is Engineer, Mr. Paul W. Edwards, Associate Engineer, and Mr. Richard L. Hanson, Assistant Engineer, in the same Division. The publication of this review in the N.F.P.A. QUARTERLY has been authorized by the U. S. Department of Agriculture.

MAY 8, 1934. PAINESVILLE, O. Five workmen killed, one injured and property loss of $100,000 resulted from explosion of aluminum powder.

JUNE 6, 1934. BALTIMORE, MD. Explosion of derris root dust at insecticide plant.

JUNE 8, 1934. MINNEAPOLIS, MINN. Explosion of flour dust in Washburn Crosby "C" mill. Two workmen injured, $10,000 damage. Flash opened 52 sprinkler heads.

JUNE 12, 1934. WEST MILWAUKEE, WIS. Explosion of malt dust during fire fighting operations, resulting in approximately $35,000 damage.

JUNE 19, 1934. NASHVILLE, TENN. Feed dust explosion. Loss, $10,000.

JUNE 22, 1934. TRACY, MINN. Dust explosion in small country grain handling plant injured four men.

JULY 12, 1934. CHICAGO, ILL. Explosion of cocoa dust resulted in loss of three lives, injuries to three others, and property damage of approximately $15,000.

The thirteen explosions during this period caused the loss of nineteen lives, injuries to forty-two other people, and property damage of approximately $1,000,000. The results of the investigations of the last eleven explosions are reviewed in this article.*

Wood Dust Explosion in Chair Factory.

Cleveland, Ohio.

At 4:23 P.M. on March 9, 1934, a dust explosion occurred at the Marble and Shattuck Chair Company plant in Cleveland, Ohio. The explosion flashed through a branch of the dust-collecting system and burned five men. Three of the men were seriously burned and one fatally. The dust collection system was damaged to the extent of about $800.

Wood Waste Disposal System.

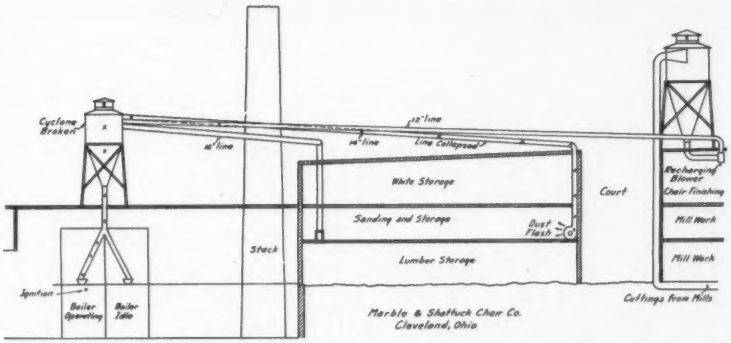
The Marble and Shattuck Chair Company manufactures high grade commercial chairs, using birch, oak, and walnut. The finer cuttings from all saws, milling, and sanding machines were concentrated in one cyclone on top of the boiler house. This wood waste dropped directly from the cyclone collector to the Dutch oven or auxiliary fire box in the boiler. There were two such boilers, only one of which was operated at a time.

The dust or shavings collection came to this cyclone from three separate lines. One line carried recharged wood waste from a large cyclone on the mill house. This line carried all of the coarser waste of the system. The other two duct lines, the smaller of which was involved in the explosion, were from independent blower systems in the sanding room. This system had a 14-inch duct line served by a fan of 4800 cubic feet per minute capacity. The sketch shows the relative location of this system with respect to the rest of the plant.

Story of the Explosion.

The sanding and milling machinery had been shut down about 4:15 P.M., to permit a clean-up of machines before the week-end shutdown. Though all

*The report of Dr. David J. Price on the explosion of malt dust in Buffalo on January 24, 1934, was published in the QUARTERLY, July 1934, Vol. 28, No. 1. It is also available in pamphlet form from the Executive Office of the N.F.P.A.



Sketch showing dust collection system involved in fire and explosion of March 9, 1934. The path of travel of the explosion is indicated by small crosses in the ducts.

blowers were operating, there was no material going through any of the ducts except from that part of the system on the court side of the sanding room. Two men were sweeping up an accumulation of dust from around three sanding machines. This dust was being pushed into an adjacent floor sweep, when a blast of flame came out of the sweep and hoods, severely burning the two men and the foreman who was standing near by. Another man rushed up with a fire extinguisher and he, too, was burned by the flames which had not quite subsided or by the flaming clothing of the other men. A fifth man received minor burns in attempting to extinguish the flaming clothing of those in the path of the blast. One of the two sweepers died after five days.

The material damage from the explosion consisted of the distortion of the butterfly check in the shavings spout leading to the Dutch oven, the bursting of the cyclone above the boilers, the collapse of the duct line leading from the fan system where the men were sweeping, damage to the fan rotor and a burst fan housing. There was other incidental damage, such as the shifting of the fan on its base. The fan blades on one side of the rotor were bent back at an angle of 45°, indicating how short was the interval of explosion pressure, the fan operating at 1200 R.P.M.

Cause of the Explosion.

As the explosion probably occurred, the man sweeping had an accumulation of fluffy fines from around the adjacent machines all ready to be brushed into the floor sweep. One push of the broom and a dust cloud formed in the system which, when whisked into the fire box, caused a back flash sufficient to rush back past the butterfly check damper into the cyclone. Here it met a second brush of dust and started back through the dust line against the draft of the fan. Third or fourth sweeps of the broom enabled it to quickly complete the back flash all the way to the fan and floor sweep.

There have been cases before where ignition of dust at the boiler has flashed back to the cyclone, but never farther back into the system. There is no reason to believe that the fan was not delivering its usual volume of air.

A sample of the dust being fed into the floor sweep was obtained. This dust was largely black walnut and of very fine fluffy shreds in nature. A screen analysis showed it to contain 11 per cent which would not pass a 30-mesh screen, and 46 per cent passed 80-mesh. Because of its shredded condition it did not screen well and in a dust flash even the coarser portions would contribute much to the propagation. When the portion which passed an 80-mesh screen was tested for explosibility in the laboratory, the tests in the explosion bomb produced a pressure of 20 pounds per square inch at a concentration of 0.1 ounce per cubic foot of air and 45 pounds per square inch at a concentration of 0.5 ounce per cubic foot of air. These figures are comparable to those normally experienced with other hard woods.

At the time of this explosion a safety code for the prevention of dust explosions in wood-working plants had just been completed by the Dust Explosion Hazards Committee of the National Fire Protection Association and was awaiting final consideration at the annual meeting of the organization. The code has since been adopted. The recommendations of the code were adhered to in the restoration of the equipment in the Marble and Shattuck plant.

An interesting aftermath to this explosion came on Tuesday, March 20, when a boiler inspector came to inspect the boiler which had been subjected to the explosion. He used an open torch as had been his habit for twenty years of such service. He had set the torch down inside the boiler and was tapping the pipes. An accumulation of dust on the tubes since the explosion was dislodged by his tapping and ignited by the open torch. Luckily the flash passed over his head, but the inspector developed such respect for the hazard of flammable dust that he promised to adopt an electric torch immediately.

White Corn Dust Explosion.

Wichita Falls, Texas.

On Tuesday afternoon, March 13, 1934, shortly after one o'clock, an explosion occurred at the Wichita Mill and Elevator Company plant (a subsidiary of the General Mills, Inc.) at Wichita Falls, Texas. The explosion, which was confined principally to the old workhouse, resulted in the death of one employee, who died from burns about six hours after the explosion, and injuries to four others, one of whom was seriously burned. The estimated damage was $100,000 for buildings and $92,000 for stock, making a total estimated explosion and fire loss of about $192,000.

Description of Plant.

The old workhouse, known as Elevator B, was built in 1914 and had a capacity of 60,000 bushels. The elevator section was 36 x 54 feet in size and

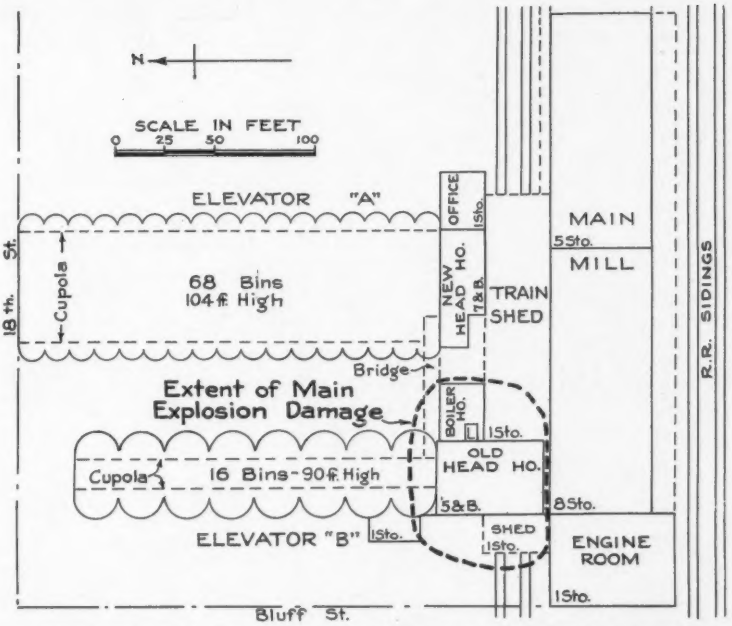


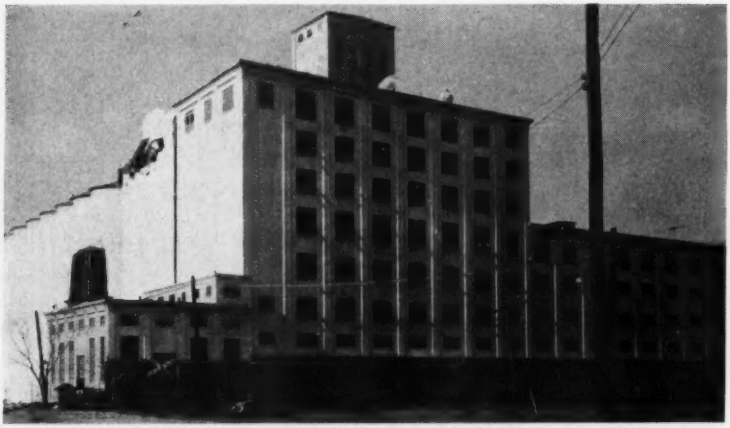
Diagram showing extent of damage to plant of Wichita Mill and Elevator Co., Wichita Falls, Tex., as the result of dust explosion of March 13, 1934.

158 feet high. It included a one-story heating plant and a battery of concrete grain storage tanks 90 feet high, having a storage capacity at the time of the explosion of 650,000 bushels. The mill section, erected in 1918, adjoined the elevator on the south. It comprised a one-story room, an eight-story mill building, and a five-story warehouse.

The new cleaning and storage unit was built in 1930. It consisted of an elevator, known as Elevator A, about 186 feet high, and a large battery of concrete grain storage tanks about 104 feet high with a storage capacity of 1,200,000 bushels. This unit was east of and parallel to the original unit.

A train shed, equal to two stories in height, was located between the two workhouse units, which were connected only by a covered all-steel bridge. The entire plant was of modern fire-resistive construction, representing an approximate value of $1,200,000.

The old workhouse had six elevator legs. It was equipped throughout with dust collection systems, which supplied suction to the sweep lines, belt tailing hoods, receiving belt hoods and cleaners and bin discharges, and provided for the collection and removal of dust from all points in the house where dust was produced or accumulated. No provision was made for venting



View showing destruction of upper portion of old workhouse. Storage section on the left and mill in the foreground. The top of the new elevator rises above the mill in the background.

either the storage bins, garners, or elevator legs, which was typical of warehouses constructed at the time this house was built.

Story of the Explosion.

The investigation indicates that there were at least two explosions, both occurring in the old workhouse. A damaged circuit of the fire alarm system registered a trouble tap at about 1:05 P.M., and this is the time of the primary explosion as fixed by the Wichita Falls fire department. Statements of witnesses also indicate that the explosions occurred between 1:05 and 1:10 P.M., showing that only a short period of time elapsed between the resumption of work after the noon hour and the time of the explosions.

At the time of the explosions, workmen were engaged in cleaning white corn preparatory to sending it over to the mill for the production of corn meal. A short time before lunch approximately 1500 bushels of white corn were taken from storage bins and placed in the scale in the old house. This corn had been in storage in these bins about eighteen days. There was no evidence of heating prior to the time the corn was put into the scale.

Immediately after the lunch hour one of the workmen started the white corn through the scale to a cleaner bin, which had a capacity of 3200 bushels. From this bin the corn passed to a Prinz and Rau cleaner (4000 bushels per hour capacity) located on the second floor of the old house. The corn passed through the cleaning process, entered a cleaner leg and was elevated to a storage bin, which also had a capacity of approximately 3200 bushels. From this bin the cleaned corn was usually taken to the mill by means of a screw conveyor, but it was not going over to the mill at the time the explosion occurred.

Débris from old workhouse piled up in track shed following explosion.

In addition to this cleaning unit there were three units of the dust-collection system in operation. The electric current was on and the necessary motors in connection with the cleaning operations and the dust collection fans were in operation, as was the lighting equipment.

Effects of the Explosion.

The major damage was practically confined to the old workhouse section. The explosion also badly damaged the lower part of the old elevator and the equipment. The pits at the train shed were wrecked, and there was evidence of considerable violence under the train shed.

In the basement of the old house there was a large quantity of dismantled equipment, and under the storage tanks were evidences of considerable pressure and suction. It was easy to determine the bins that were empty at the time of the explosion by the effect on the discharge spouts in the basement. The spout of every empty bin was drawn up into the bottom of the bin and was very badly distorted, indicating considerable suction on the interior of these empty bins. There was little evidence of fire in the tunnel under these storage tanks, but a burned shutter blown into one of the compartments underneath the bins is positive proof that flame traveled through this section.

On the first floor of the old house there was evidence of considerable fire. In fact there seemed to be more evidence of fire at this point than at any other point in the old house. There were two cleaning machines on this floor, not in operation at the time of the explosion. Both were very badly burned.

On the second floor there were two cleaners. The Prinz and Rau cleaner was not badly damaged. One of the legs was badly charred near the floor, and

Top of old workhouse completely wrecked by explosion. Bridge connecting old and new houses across which injured weighman was carried may be seen in foreground.

the bag attached to the cleaner was completely burned. The employee who was operating this cleaner, and presumably near it, was severely burned. He was taken to a hospital, where he died that evening. This employee was not able to make any statement and therefore it was impossible to determine definitely just where he was and what he was doing at the time of the explosion. The other cleaner showed but little evidence of fire. It was not operating at the time of the explosion.

It was not possible during the investigation to reach a point in the old elevator above the top of the second floor. The wreckage, however, could be observed from the roof of the mill building. The top of the old house (the upper 70 feet of the structure) was completely demolished. The covered steel bridge that connected the two elevator units was wrecked and dropped from its position to the top of the tanks on the old house.

The weighman who was in the scale office on the second floor of the old house at the time of the explosion, dropped, seated in his chair, a vertical distance of about 20 to 25 feet, and was covered with débris. He was rescued after about $1\frac{1}{2}$ hours and had to be carried over the wrecked bridge and out through the mill building. At the hospital where he was taken he was found to be badly burned and bruised.

The rescue of this weighman was an example of heroic effort, as the uncertainty of the stability of the bridge, which had dropped from its permanent position, and its wreckage by the explosion made it most unusual.

Conclusions As to Origin of Explosion.

In the investigation of dust explosions of this character experience has indicated that the possible cause of the original dust ignition, or the primary explosion, is, as a general rule, directly associated with the equipment or processes in actual operation at the time. This investigation indicated that the point of origin of the first explosion was in the vicinity of cleaner bin No. 14 in the old house. The cleaner on the second floor showed no evidence of fire or effects of the explosion, while the entire structure above was badly damaged.

Cleaner bin No. 14 had been emptied of wheat shortly before the noon hour, and approximately 1500 bushels of white corn had been placed in the scale before the men went to lunch. The corn had been running from the scale to this cleaner bin but a short time when the first explosion occurred. This bin had a capacity of approximately 3200 bushels. The grain cleaner on the second floor of the old house had a capacity of 4000 bushels per hour. In the few minutes of actual operation approximately 100 bushels had passed from the scale through bin No. 14, so that only a small quantity had passed through the cleaner. It can readily be seen, therefore, that as cleaner bin No. 14 was completely emptied before noon, the white corn running into the bin from the scale above would create a heavy dust cloud in this bin. There seems to have been sufficient corn at the bottom of the bin to serve as a "choke" to prevent the fire from flashing down into the grain-cleaner below, which showed very little evidence of fire or explosion damage.

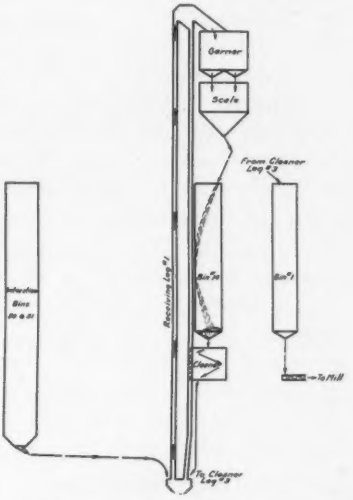


Diagram showing path of white corn at time of explosion.

The original ignition of the dust cloud in cleaner bin No. 14 resulted in the first or primary explosion at this point in the old house. It is believed that the explosion in this bin blew into the elevator legs and possibly into near-by empty bins in the old house. This flash of fire through the elevator legs could have spread to the basement and lower floors and also to the top of the house, resulting in the second explosion when the flame communicated to empty bins in the storage section.

The flame from the burning dust cloud could have flashed through the dust-collecting systems, through the various intake points, and spread to the

cyclones and the dust house. The fact that the dust house had only recently been cleaned provided a larger area for dust concentration at this point than would normally be the case. If the flame was propagating at sufficient velocity it would have been possible for it to enter the operating systems even against the air currents with lower velocities.

There were two distinct major explosions, the second being more violent than the first. This is the normal procedure in dust explosions of this character, and it indicates the propagation of flame from the point of origin of ignition of the primary dust cloud to a second point some distance away, where the dislodged dust is forced into the air in explosive proportions, and the second explosion follows.

With this in mind it can be reasonably concluded that the original ignition in bin No. 14 was not generally observed in so far as actually hearing the report was concerned. Several of the workmen, however, believe that they heard three distinct reports. The propagation of the original explosion in bin No. 14 to a point at the lower part of the house could have resulted in an explosion in the tunnel and under the train shed. This flame could then have traveled through the first floor, causing the extensive fire damage at this point, and on up to the second floor where the cleaner man was working.

The explosion in the lower part of the house apparently preceded, by a very short interval, the second or more violent explosion on the top of the workhouse where the flash of flame spread through the empty storage bins.

The fire from the explosion at the upper part of the workhouse entered the new house either through the dust collection pipe in the overhead bridge, through the bridge itself, or through the open windows. The evidence shows that it exerted sufficient pressure in the new house to open up the garner hood at the top.

Possible Sources of Ignition.

In reaching the conclusion that the original explosion probably occurred in cleaner bin No. 14, it is of course necessary to advance certain possible sources of ignition. The creation of an explosive mixture of white corn dust and air in this bin during the movement of the corn from the scale is the first requisite. This explosive concentration then must be ignited before the original or primary explosion can take place.

In transferring grain from scales to bins preparatory to cleaning operations the following possible causes have been developed in investigations of similar explosions, and should be considered in this case.

1. Static electricity produced by friction of grain entering the bin.

2. Heating of the grain during previous storage, resulting in fire in the scale and bin.

3. Sparks or fire from foreign material in the grain entering the bin.

It does not appear that the first two possible causes listed have any application in this case. Weather conditions at the time of the explosion were not favorable for the production of static electricity. The examination of the corn on the morning of the explosion showed that it was in normal condition and there was no evidence of excessive heating. These two causes can therefore be eliminated from consideration.

It appears, therefore, that there was foreign material of some sort in the white corn when it passed from the scale to the cleaner. It probably consisted of pieces of metal which would make a noise in passing into the bin, and would account for the "unusual sounds" heard by one of the workmen prior to the explosion, and which he states he tried to locate. This metal in the stream of white corn as it entered the bin would, under favorable conditions, produce metallic sparks that could ignite the suspended dust cloud.

Dust Explosion in a Country Elevator.

Amarillo, Texas.

On Friday morning, April 20, 1934, about 11 o'clock, a dust explosion occurred at the Central Grain and Elevator Company plant at Amarillo, Texas. The explosion, which was confined to the elevator, resulted in injuries to three men and damage to property and stocks of approximately $75,000.

The explosion was investigated by the Chemical Engineering Division of the Bureau of Chemistry and Soils, U. S. Department of Agriculture, in cooperation with the Bureau of Agricultural Economics. The occurrence is of importance since the explosion took place in what might be considered a country elevator and indicates definitely that dust explosions can occur in this type of grain-handling plant.

Description of Plant.

The plant, which was built in 1929, consisted of a grain elevator and two storage warehouses of frame metal-clad construction. Grain was run from railroad cars and trucks through an outside open grating and concrete chute to the elevator boots, and elevated by means of ordinary bucket elevators to the distributing spouts in the head house. There were no processing operations, but grain cleaners were installed on the ground floor. The electrical equipment consisted of three induction motors with no exposed moving parts, one for each elevator leg and one for the man hoist, located on the distributing floor above the bins. There were two smaller motors of the same type on the separator and fan at the ground floor level. All wiring was in approved conduit, but lamp globes and switches were not of the dust proof type.

The plant was located about two miles from the center of the city and about 15 blocks from the nearest fire station with pumper. A 6-inch circulating city water main supplied two three-way fire hydrants within 250 and 500

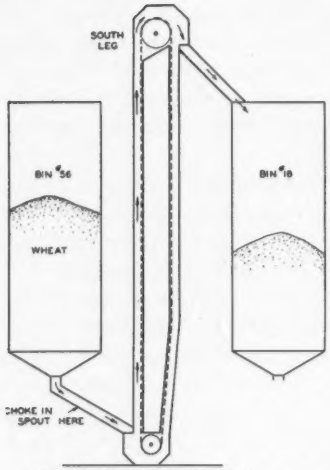
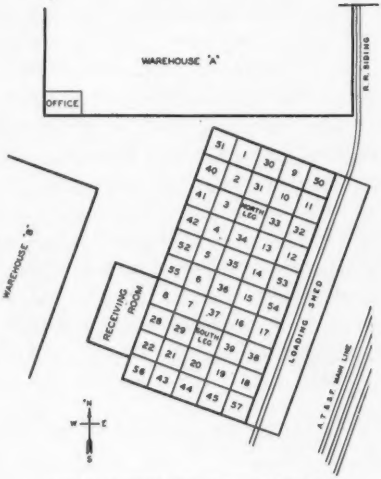


DIAGRAM SHOWING FLOW OF GRAIN AT TIME OF EXPLOSION.



PLAN OF ELEVATOR AND ADJACENT BUILDINGS

feet of the plant. A flow test made by the Texas Inspection Bureau on January 19, 1934, indicated an available supply of 1115 gallons per minute.

The plant was equipped with automatic sprinklers. A 6-inch dry pipe valve and exhauster, installed in a brick valve house on the north side of warehouse "B," was supplied by a 6-inch main extending from the city main. This valve controlled all three buildings, with 153 sprinklers in warehouse "B," 135 sprinklers fed by a 5-inch extension line to warehouse "A," and 120 sprinklers on a 4-inch extension to the elevator. A water motor gong and fire department pumper connection was located on the valve house wall.

Story of the Explosion.

The explosion occurred about 11 o'clock in the morning. The elevator operator was the only employee on duty and at the time of the explosion he was being visited by two men, not employees at the elevator.

From the information obtained in the investigation, it appears that the operator had loaded a car that morning, commencing work at 7:00 A.M. This car was loaded on the *north* leg, and the loading operations had been completed at least one-half hour prior to the explosion. At the time of the explosion, wheat was being turned on the *south* leg, from bin No. 56 to bin No. 18 (see diagram). This turning operation apparently had been carried on the previous afternoon, but had not been completed. This operation was entirely a transfer of wheat from one bin to the other, and no grain cleaners were in operation at the time.

The upper part of the head house was destroyed by the explosion, and the elevator was a total loss as a result of the rapid spread of the resultant fire.

View of Central Elevator at Amarillo, Texas, showing destruction by fire following explosion of wheat dust.

The sprinkler system was wrecked by the explosion and rendered useless. It seems likely that the 4-inch riser was broken, because of the subsequent effect on the pressure. The condition of the ruins, however, made it impossible to verify this fact. Warehouse "B" took fire shortly after the arrival of the fire department, and as the sprinklers had been shut off, the east half of the building was burned. Warehouse "A" was not involved in the fire, and no sprinklers in this building opened, but a portion of the building was damaged by falling débris from the elevator head house.

The three men in the elevator at the time of the explosion were severely burned about the face and hands, the elevator operator the most critically. At the time of the explosion, the men were standing approximately eight feet from the southeast door of the work floor. They stated that they were enveloped in flames and were blown out of the doorway.

Cause of the Explosion.

The cause of this explosion must necessarily be associated with the transfer of the wheat from one bin to another, by means of the south leg. We can therefore consider the possible causes in connection with this operation.

(a) Friction of elevator buckets in leg, resulting in sparks or fire causing ignition of dust in leg.

(b) Choke in elevator leg itself, resulting in friction fire and ignition of dust in leg.

(c) Choke or obstruction in outlet spout from bin No. 56, resulting in friction in elevator leg well and spreading of fire to top of leg.

The investigation indicates that the point of origin of the first explosion

was in the south leg, blowing out the top of the leg and spreading to bin No. 18 and the other bins at the top of the house.

The week before the explosion occurred an elevator builder of long experience had been checking the machinery and making necessary adjustments and repairs. It is quite reasonable, therefore, to assume that the possibility of (a) friction of elevator buckets in the south leg and (b) choke in the elevator leg itself, would be eliminated.

It was revealed that there was a choke in the spout from bin No. 56 to the leg well, which the elevator operator was preparing to remove when the explosion occurred. It would appear that this choke had not been removed before the explosion took place, for it is quite evident that the original explosion occurred in the south leg and was directly associated with this choke. The nature of the obstruction may have been such that it caused sufficient friction at the boot of the leg to ignite the suspended dust cloud and travel upwards, resulting in an explosion at the top. This explosion would blow off the top of the leg and spread to the various bins throughout the house. This would result in a secondary explosion with considerable flame, and the fire following would involve the entire house.

Conclusions.

This explosion shows the need for adequate venting area in the construction of country grain elevators, as well as in the terminal houses.* The need for vents in elevator or lofter heads and leg wells is definitely indicated, and the venting of garners, bins and storage spaces should be given thorough consideration.

The desirability of definite provision for removal of foreign material from grain is forcibly demonstrated by this explosion.

The value of closed storage bins and the undesirability of inter-connections between storage bins is indicated. Open bins and bins with direct connections permit the rapid propagation of flame over the top of the bins and extend the violence of the explosion.

Cleanliness and good housekeeping are always a matter of prime importance and should be practiced to the highest degree in country grain elevators. It must be recognized that a dust explosion cannot occur unless dust is present.

Proper provision should be made for adequate protection of electrical appliances and equipment. Special attention should be given to the protection of electric light bulbs with outer dust proof globes and wire guards to prevent breakage.

*The results of venting tests by the Bureau of Chemistry and Soils are reported in an article entitled, "Venting Dust Explosions," by Hylton R. Brown and Richard L. Hanson, which appeared in the April, 1933, QUARTERLY, Vol. 26, No. 4.

Explosion in a Feed Mill.

Riverdale, Illinois.

About 3:20 A.M. on April 26, 1934, an explosion occurred at the Arcady Farms Milling Company's plant at Riverdale, Illinois. The explosion was followed by fire. No employees were injured, but the property loss amounted to about $300,000. The plant consisted of a group of fire-resistive and frame metal-clad buildings, all mutually exposed and with protected and unprotected communications between buildings in the form of passageways, belt conveyor galleries, wind trunking and spouts. The explosion originated in the mill building and the fire which followed spread into the warehouse adjoining.

The mill had been operating day and night, grinding feed, and about twelve men were employed at the time. Hammer mills were in use and it was in this section on the second floor that the first flash was noticed. An employee rushed to a fire alarm box on the fifth floor and turned in an alarm, but before he reached the box the second explosion occurred and spread the fire over a wide area. The flames shot through openings in fire walls before fire doors could operate and spread rapidly upward through manlift and stair openings and elevator legs and spouts. Two other alarms were received from different boxes in the plant, and additional calls for aid were made after the first fire companies arrived.

Fire doors on openings between sections of the plant were closed manually and the firemen were able to confine the fire to the fire-resistive sections in which it originated. The loss consisted principally of damage to grain and feed by fire and water and spalling of walls and ceiling. Electrical equipment was seriously affected by fire and water.

This explosion apparently originated in the grinding section of the plant where it could have been caused by an electrical spark or by foreign material entering the mills with the grain being ground, although the grinding unit which figured in this explosion was equipped with both magnetic separation and aspiration for the removal of such materials as are not attracted by magnetic force. Evidently the original explosion was not extremely violent, but the second one created a pressure wave within the building that made it difficult for the foreman to hang on to the manlift on which he was riding to an upper floor.

The value of fire-resistive construction was effectively demonstrated. Fire doors which were closed between sections were effective in confining the fire. At other points where fire doors were open the flames shot through the openings before they could be closed.

NOTE: See Regulations for the Prevention of Dust Explosions in Flour and Feed Mills for general recommendations.

Terminal Grain Elevator Explosion.

St. Louis, Mo.

On May 8, 1934, a dust explosion occurred at the Missouri Pacific R. R. elevator at St. Louis, Missouri. This plant, a modern fire-resistive terminal elevator of about 4,000,000 bushels capacity, was leased to and operated by the Continental Grain Export Company. The explosion resulted in the death of seven workmen, principally from burns, and injuries to eight others. The property loss was estimated in the vicinity of $125,000.

This elevator consists of the workhouse, storage section, marine tower, drier, and several small buildings. The workhouse, a reinforced concrete structure about 48 x 112 feet and 224 feet high, contains 69 bins with capacities ranging from 1000 to 6400 bushels. There are ten elevator legs in the workhouse, three on the east side installed to serve the cleaning machinery, and seven on the west side with seven garners and scales and the necessary spouts to handle incoming or outgoing grain shipments. A conveyor belt running the length of the distributing floor can be used to carry grain to bins or through an enclosed bridge or gallery to the drier. From the bin floor of the workhouse six conveyor belts run through steel frame metal-clad bridges or galleries to the storage section located about 70 feet west of the workhouse.

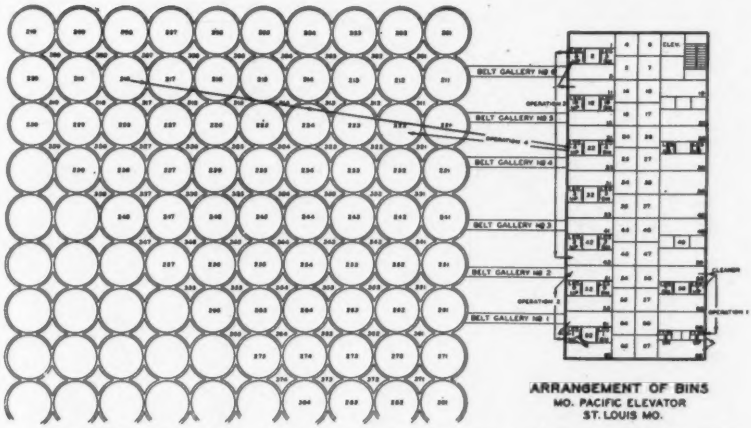
Adjoining the workhouse on the west side at the ground or work floor level is the track shed, and directly above the track shed are six conveyor belts used to carry grain from the basement of the storage section to the workhouse. A tunnel containing a conveyor belt extends from the basement of the workhouse to the drier located north of the workhouse, and three tunnels containing conveyor belts extend from the basement of the workhouse to unloading pits under the track shed, but there are no direct connections to the basement of the storage section.

The storage section, marine tower and other sections of the plant were not seriously affected by the explosion and need no special description.

Four separate operations were in progress when the explosion occurred, and at least three of these contributed to the spread of the explosion throughout the workhouse. In all of these operations corn which had been in the house for some time was being handled. The four operations may be described briefly as follows:

1. In the southeast corner of the workhouse corn was being drawn from workhouse bin No. 58 to the north cleaner on the work floor. The corn passing over this cleaner entered the boot of elevator leg No. 7 and was elevated to the top of the house, where it was discharged into scale No. 9. The screenings from the cleaner entered a screw conveyor in the basement, which carried them to the boot of leg No. 6. From this point they were elevated to the top of the house and discharged through a spout into bin No. 69 in the extreme southeast corner of the building.

2. In the southwest corner of the workhouse corn was being drawn from bin No. 61 and allowed to run over a wooden trough or chute with a screen or mesh bottom set up on



Arrangement of bins and sequence of operations at time of explosion, Missouri Pacific Elevator, St. Louis, Missouri.

the first floor, and extending from the bin discharge to the grating in the floor, covering an opening into the boot of leg No. 1. This leg elevated the grain to the top of the house and discharged it through No. 1 garner and scale and a Mayo spout into bin No. 51.

3. In the northwest corner of the building an operation quite similar to No. 2 was in progress. Corn was being drawn from bin No. 11 and allowed to run over a screen-bottom chute to the floor grating covering the opening into the boot of leg No. 5. This corn was elevated to the top of the house and discharged through No. 5 garner and scale on to a conveyor belt on the distributing floor which carried it to bin No. 43.

4. The fourth operation, and one which apparently played but a minor part in the explosion, consisted of the transfer of corn from one bin in the storage section through the workhouse and back to the storage tanks.

Origin and Cause of the Explosion.

An examination of the damaged equipment indicates that the path of flame travel was upward through the house from the work floor level, and that the final heavy and destructive explosion occurred in the upper part of the house when the dust cloud around the scales and garners was ignited by the flash from below. Testimony of witnesses who saw flames rushing upward through the house and of others who heard the initial explosion or saw a flash on the work floor leaves little doubt that the point of origin was at the south end of the first floor of the workhouse. Two separate operations were in progress at this point, namely, the running of corn over the cleaner in the southeast corner and the running of corn over the screen-bottom chute in the southwest corner. The running of corn over the screen was the operation that produced the heavy dust cloud, and the fire-blackened walls in the southwest corner as well as an examination of the damaged equipment indicate that the original ignition was caused at this point by a spark or friction fire in the boot of No. 1 leg, into which the corn was flowing as it passed over the chute.

Southwest corner of Missouri Pacific elevator, showing value of large window area which provided vent for the release of explosion pressure.

Conclusions.

This explosion has served as a proving ground for many of the recommendations made in the past for fire and explosion protection. Credit should be given to both the builders and operators for their efforts to provide this protection. Many of the features incorporated in the construction have been mentioned, but it seems desirable at this point to refer to them and to some of the operating practices in the form of recommendations to be considered in the reconstruction and operation of grain-handling plants.

1. Fire-resistive construction prevented a heavy fire loss in this case and is recommended for all plants.

2. Covered bins limited the extent of the explosion and protected the contents. Their use is recommended.

3. Smooth construction and the elimination of ledges made cleaning easy, prevented heavy overhead dust accumulations, and is generally recommended.

Southeast corner of bin floor of Missouri Pacific elevator, showing damaged walls of screenings bin.

4. Floor sweeps and dust removal equipment were of value in keeping this plant clean. Such equipment should be installed wherever dust is produced or accumulates.

5. It is generally agreed that the large window area served as a vent for the explosion pressure and prevented the complete destruction of at least the top of the workhouse. The explosion demonstrated very effectively the value of the recommendation that not less than 1 sq ft. of vent be provided for each 80 cu. ft. of volume in a cubical-shaped structure. In this case there was about 1 sq. ft. for each 75 cu. ft. The use of top-hinged sash or frames set less firmly in the concrete wall would have been even more effective.

6. Garner vents were used and have proved effective in carrying at least a part of the dust outside of the building. They are not intended to serve as explosion pressure releases. A cloth seal or curtain between the garner and scale serves to retain the fine dust within the scale hopper and permit the use of scale vents, which are recommended.

7. Elevator head vents are effective in preventing dust dissemination due to "blowing" in the leg and permit the leg to draw in or discharge air as required. They are not intended to release high explosion pressures, but if sufficiently large will serve to protect the head and upper part of the leg. The extension of the entire top of the head housing through the roof, where it can be covered with a light weather cap is recommended.

8. Segregation of particularly dusty operations or the dividing of the plant into units is recommended. The elimination of direct tunnel connections between the workhouse and storage section and the placing of steel partitions in the galleries between these two sections served to segregate the workhouse and prevented the spread of the explosion to the storage section.

9. The use of automatic fire doors to close belt openings through walls in case of fire was proved practicable in this explosion. All of the six units installed operated perfectly.

10. The use of sounding ropes to measure the contents of bins as practiced at this plant is preferable to the use of extension lights, but lead or nonsparking metal should be used instead of iron.

11. The use of deflector plates or some method of deflecting grain entering a bin so that it will drop straight down and not strike against the side of the bin is recommended. Metal or foreign material in the grain may strike a spark when it is thrown against the side of the bin.

12. Further attention should be given to the development of separators capable of removing metal and other foreign material from grain while it is being handled in the house.

13. The use of coarse mesh screens with openings 1½ to 2 inches has been recommended for use over the gratings covering pits in track sheds while unloading grain which may contain foreign material. The use of such screens over gratings inside the house to cover openings to bins or boots also may be desirable.

14. It is recomended that the use of open chutes be discontinued in accordance with paragraph 415 in the Safety Code for the Prevention of Dust Explosions in Terminal Grain Elevators as prepared by the Dust Explosion Hazards Committee of the National Fire Protection Association.

Aluminum Powder Explosion.

Painesville, Ohio.

On Saturday morning, May 19, 1934, at eleven o'clock a fire followed by an explosion occurred in the Premier Bronze Company's plant located just beyond the corporate limits of Painesville, Ohio. The explosion, which completely destroyed the plant, resulted in the death of five of the six men who were in the building at the time of the explosion. Three of the men were killed instantly, the other two died within a few hours. The sixth man, who was evidently blown out with the wall, suffered from minor burns and shock. The estimated damage was approximately $80,000 to the building and $20,000 to the stock of finished aluminum powder and equipment, making a total loss of $100,000.

Description of Plant.

The building in which the explosion occurred was built by an electric railway company and used as a power plant until the line was discontinued. In 1928 it was purchased by the Premier Bronze Powder Company, and had been used for the manufacture of aluminum powder until the explosion.

The structure had brick walls extending about 30 feet to a tile roof supported by exposed steel trusses. Adjoining the west wall was a smaller addition of the same height and construction. All walls were twelve inches thick except a 16-inch division wall which ran north and south through the building,

Ruins of Premier Bronze Company's plant, Painesville, Ohio, following explosion of aluminum powder.

dividing it into two rooms. A large brick stack 210 feet high and 16 feet inside diameter with walls 2 feet thick at the base was connected to the main plant by means of a passageway of steel construction. The stack, the top of which was covered with metal, housed a classifying screen and dust collector.

Floors were of concrete construction. The floor level of the east room was five feet below the level of the west room and the floor of the addition was about one foot above the adjoining floor. An open pit, which extended about ten feet below the floor of the west room, and situated near the center of the division wall, was used as storage for raw material. A basement, under part of the building, housed the boiler, a machine shop, and a storage room.

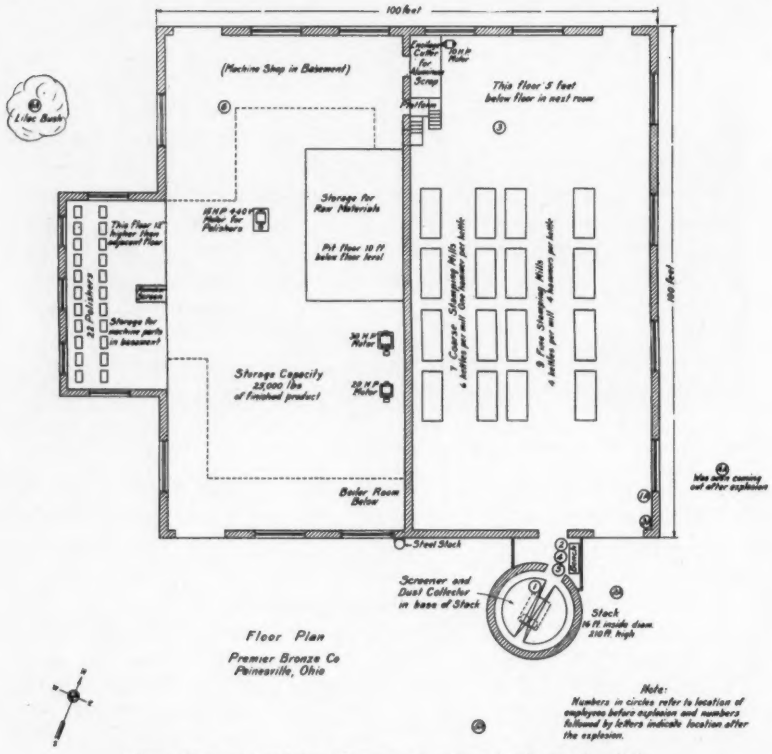
The process consisted essentially of cutting thin aluminum scrap and foil in an ensilage cutter and passing this material through coarse and fine stamp mills. The product was screened and then polished in the polishing machines. It was screened again and placed in steel drums ready for shipment.

All of the equipment in this plant was said to have been in good condition. The stamping mills, polishing machines, and screens were electrically grounded to remove static electricity. Dust proof globes were used to protect the electric incandescent lamps. Reports indicated that the plant was kept clean and free from dust. A total of 15 men was normally employed in this plant, which operated 24 hours per day on four six-hour shifts.

Story of the Fire and Explosion.

The plant was completely destroyed by the first explosion. A number of minor explosions followed in the ruins for a period of several hours and one rather severe explosion occurred 1½ hours after the initial explosion.

On the day of the fire the shift that went off duty at 7:00 A.M. had been given instructions to stop production in the east end of the plant at about


100 feet
Lilac Bush
(Machine Shop in Basement)
Emery Cutter for Aluminum Scrap
Pan p Motor
Partition
This Floor 3 feet below floor in next room
Storage for Raw Materials
Pit Floor 10 ft below floor level
This Floor 10" higher than adjacent Floor
Screen
Storage for machine parts in basement
Storage Capacity 25,000 lbs of finished product
Boiler Room Below
7 Coarse Stamping Mills 4 bottles per mill One Number per bottle
9 Fine Stamping Mills 4 bottles per mill 4 Numbers per bottle
100 feet
Steel Stack
Screener and Dust Collector in base of Stack
Stack 16 ft. inside diam. 210 ft. high
Floor Plan
Premier Bronze Co
Painesville, Ohio
Note:
Numbers in circles refer to location of employees before explosion and numbers followed by letters indicate location after the explosion.

Floor plan of Premier Bronze Co. plant, Painesville, Ohio.

5:00 A.M. That indicates that the polishing department in the west end of the building was the only department operating at the time of the fire and explosion. From five until seven o'clock the men were engaged in cleaning the plant in preparation for some repair work in the stack. The superintendent stated that he considered the plant clean. The repair work consisted in building a metal cat-walk around the inside of the stack in order to make the dust collector more readily accessible.

At the time of the fire one man, (1),* was working in the stack, and three others, (2), (4), and (5) were working at a bench in the passageway between the stack and the east part of the plant. Another employee, (3), was cleaning or sweeping in the east room. The only man, (6), who was not killed was operating the polishing machines near the northwest corner of the plant.

*The numbers indicate locations of employees before and after explosions—see floor plan.

The explosion occurred at 11:00 A.M. A general alarm was sent to the fire and police departments, and the Lake County Memorial Hospital by residents on the hill overlooking the valley where the plant was located. One man, (6A), was found in a lilac bush about 50 feet from the west side of the plant. Apparently he had been blown out with the wall. He was taken to the hospital where his injuries were described as lacerations, burns and shock.

Another employee, (5A), was found several hundred feet south of the plant running toward the river, where he hoped to extinguish his burning clothes. When found his clothes were practically all burned off. He was taken to the hospital, where he died the next day. Another man, (4A), was found just east of the plant. It was reported that he was seen crawling over the débris just after the explosion. He was terribly burned and died later.

The three remaining employees who were in the plant at the time of the explosion were reported missing. Due to danger from further explosions and the intense heat from the smoldering ruins, rescue work was not begun until late in the afternoon. Two bodies, (1A) and (3A), were found a short distance from where they had been working. The remaining body, (2A), was discovered near the stack, buried under ten feet of bricks.

The chief of the Painesville Fire Department arrived at the plant a few minutes after the explosion and ordered the plant area roped off. The fire department made no attempt to put water on the fire on account of the explosion hazard, which would result from the contact of water with hot aluminum powder.

An examination of the ruins shows that all of the walls were blown outward, with the exception of a small portion near the stack. This section may have been blown inward by an explosion which evidently occurred in the stack, for the stack was blown apart and most of it fell near its base. Portions of the roof were found at a considerable distance from the plant, but most of it apparently just collapsed after the walls were blown out. The 16-inch division wall which ran through the center of the plant was badly damaged, a portion of it being moved a few inches. The walls of the polishing room were badly cracked, but did not collapse. The windows were blown out.

An interesting feature of the explosion was exhibited by a sheet metal stack about 12 inches in diameter and probably 40 feet high, located adjacent to the south wall of the plant. This stack remained standing, although the wall adjacent was blown down and the 210-foot brick stack was demolished. This type of phenomenon has been observed in other explosions.

Cause of the Explosion.

Had it not been for the testimony of one of the injured mechanics, it is very probable that the cause of the explosion would never have been known, because the building was so completely demolished that a survey of the ruins

Explosion of aluminum powder which occurred about 1½ hours after the original explosion and fire.

could not furnish any positive information. All of the employees who were in a position to know what caused the fire and explosion were killed or died later from the results of burns and injuries.

An official of the company called at the hospital to inquire about the mechanic's condition. The latter told the official that he wished to explain what caused the fire and explosion. He said that three men, including himself, were working at a work bench in the passageway between the brick stack and the main part of the plant, and that another man was working in the stack. He stated that one of the mechanics dropped a tool, such as a hammer or cold chisel, which struck a piece of sheet metal which was lying on the floor. The resultant spark caused a fire in some aluminum powder which had accumulated there. He further stated that he told the mechanic to get a pail of sand and to build a wall around the fire with the sand; common procedure in extinguishing small aluminum fires. The employee, instead of building a wall around the fire, threw the sand on the fire. This was followed immediately by a flash from which he tried to escape and that was all he remembered.

Apparently the explosion traveled very rapidly throughout the plant, because some of the men who were killed were only a short distance from a door on the south side of the plant. The employee who was working at about the farthest point in the plant from the source of the fire and explosion, stated that he saw smoke near the floor coming into the room where he was working immediately prior to the explosion. He was found in a lilac bush about 50 feet from the west wall, evidently having been blown out with the wall.

It seems quite probable that the explosion propagated from the initial flash in the passageway in two directions, that is, into the main building and also into the brick stack. It is quite probable that the inside surface of the stack, above a point where it could be readily cleaned, contained considerable quantities of aluminum powder. This deposit was probably thrown into suspension by the pressure wave advancing before the flame front. The condition was ideal for a dust explosion to develop a tremendous pressure.

Likewise it seems logical to assume that the exposed steel truss work which supported the roof of the plant collected considerable quantities of aluminum powder. In fact it is extremely difficult to keep a plant which has very high ceilings free from dust accumulations. When this dust was thrown into suspension it probably required only a few seconds for the explosion to propagate throughout the plant. According to the only survivor's statement, the explosion evidently first reached the west room by propagating through a door in the division wall into the pit located in the west room.

Recommendations.

1. An aluminum powder plant should consist of small units sufficiently separated to prevent an explosion in one damaging another.
2. The buildings should be of light fire-resistive construction with maximum window area and other features designed to relieve high explosion pressures. All parts should be accessible for cleaning. There should be no beams or ledges to collect dust.
3. The polishing department, stamp mills, dust collectors and screening machines should be in separate buildings.
4. All machines should be electrically grounded and periodically inspected.
5. Electric lamps should have dust-proof globes with rugged wire guards. No open flames or matches should be permitted.
6. Non-sparking metals should be used instead of iron or steel wherever possible. Shoes with iron heel or steel nails should not be worn in the plant.
7. Floors, walls and ceilings should be cleaned on a regular and frequent schedule, using a portable or unit type vacuum cleaning system. All equipment should be kept in good condition to prevent the escape of powder.
8. Generous quantities of sand in suitable containers should be distributed through the plant and every employee instructed in using sand to form a wall around a fire without disturbing the dust.

Dust Explosion in Insecticide Grinding.

Baltimore, Md.

At 8:40 A.M. Wednesday, June 6, 1934, a dust explosion took place in the insecticide grinding unit of McCormick & Company, Baltimore, Md. The dust involved was ground derris root. The property damage was estimated at $4000. No one was injured.

Derris root, which is tough and fibrous in nature, was fed into a shredder, where it was reduced to a fluffy mass. This mass was drawn through a perforated plate in the base of the shredder and discharged into a cyclone collec-

tor, from which the product dropped into a bin. The shredded pulp was fed from the bin through a screw conveyor to a secondary mill for reduction to the desired fineness. The product of this mill also was collected in a cyclone. Each mill was served by a rotary blower fan and the air discharge of each cyclone passed through a bag collector for the removal of entrained fines.

The shredder handled about 2000 pounds of derris root per hour and the fine mill would grind about 500 pounds per hour. The product of the secondary grinding would reach largely a 200-mesh fineness.

On the day preceding the explosion a fire was discovered in the shredder. This was definitely traced to the shredding of a few damp bales of derris root. The dampness rendered the roots very tough and slow to shred, and the heat of grinding raised the material to the kindling point before it was reduced finely enough to be drawn through the perforated plate. The shredder was immediately shut down, the primary grinding system cleaned out, and the whole unit allowed to remain idle.

Early next morning smoke in that area again caused the management to open the shredder. Additional charred material was found. After about two hours of endeavor to remove fire from the system, the fan on the secondary unit was started preparatory to resuming grinding. A dust explosion in the cyclone collector at the secondary mill followed immediately. The explosion damage was localized at the collector, destroying the cyclone, and breaking out a thin partition and two widow sash. Four sprinklers opened and checked the flames which flashed from the cyclone vent. Firemen on their arrival put out smouldering dust in various ducts by the use of extinguishers.

This explosion is of particular interest since it is the first known case of a dust explosion in the grinding or handling of derris root, a recently introduced insecticide. Laboratory tests show ground derris root to be of about the same explosibility as corn starch.

The fire in this case undoubtedly was caused by the slow shredding of the damp bales. The fire probably was not discovered until some of the glowing, though not flaming material had passed on to the secondary mill. When the fan was started, some of the glowing material was dislodged and drawn through to the cyclone from a point beyond the screw conveyor.

This explosion shows the need for the presence of adequate clean-out openings to permit the inspection and cleaning of all parts of a grinding unit following mill fires. It is also necessary to supply sufficient air flow through a mill for cooling purposes to take care of all fluctuations in mill feed.

For the ultimate safety of a closed grinding unit handling a material of the degree of explosibility of derris root, it should be equipped to operate in an atmosphere of inert gas capable of preventing both fires and explosions.*

*N.F.P.A. Safety Code for the Use of Inert Gas for Fire and Explosion Prevention.
U. S. Department of Agriculture Bulletin No. 74—"The Value of Inert Gas as a Preventive of Dust Explosions in Grinding Equipment."

Flour Mill Dust Explosion.

Minneapolis, Minn.

An unusual accident caused a dust explosion on June 8, 1934, at the Washburn Crosby "C" Mill in Minneapolis. Two men were slightly burned. There was very little fire damage, but the flash opened 52 sprinkler heads and the flow of water through these heads for about 20 minutes caused considerable water damage. These heads were located on the fourth, fifth, sixth and seventh floors and water flowed to the basement, where it accumulated on the floor to the depth of about six inches. No water was used by the fire department because the sprinklers had checked all fire before the department arrived. The property loss amounted to about $10,000.

Story of the Explosion.

Flour bins over the packers were being filled about 12:45 A.M., and an employee on the fifth floor was examining the bins to determine how much they contained. These bins are of wooden construction and extend from the ceiling of the third floor to the sixth floor. They were connected by overhead spouting on the sixth floor and in addition there was a direct communication between the bins at the top. Inspection doors in the side of the bins were on the fifth floor.

The employee was using a portable extension light equipped with a dust proof globe and guard. It is believed that he dropped the lamp when he opened the door of bin No. 1. The shock of the fall or the weight of the lamp fixture parted the wire where it joined the socket and the arc produced ignited a cloud of flour dust in the upper part of the bin. The extension cord with the bare wire exposed at the end was found hanging in the bin and the lamp fixture was found loose in the bin.

The explosion tore up the flooring over No. 1 bin and part of No. 2 and communicated to Nos. 2, 3, and 4 bins. Practically all windows on the south side of the sixth floor were broken and woodwork in the vicinity was scorched. A number of windows in the fifth floor office enclosure were blown in. Seventeen sprinkler heads opened on this floor. The flash evidently propagated through belt holes and other floor openings to the fourth, sixth and seventh floors, because sprinkler heads opened on all of these floors. With all the fire which was evidently present, it is difficult to understand how the employee at the bin escaped injury. He was thrown several feet by the force of the explosion, but was burned only slightly and not otherwise injured. Another employee, who was oiling bearings on the floor above, had his hair slightly singed.

Recommendations.

In the safety codes for the prevention of dust explosions, prepared by the Dust Explosion Hazards Committee of the National Fire Protection Association, attention has been called to the hazard due to the use of extension cords

in bins. Flood or spot lights properly installed in the top of the bin or directed through a manhole or inspection door are recommended. Reference is also made to Sec. 3204 (j) of the National Electrical Code which covers the use of extension cords.

Malt Dust Explosion.

West Milwaukee, Wis.

An explosion of malt dust occurred on June 12, 1934, during the progress of a fire at the Kurth Malting Company's plant just outside the city limits of Milwaukee, Wisconsin. No one was injured, but the property loss amounted to about $35,000. This explosion was somewhat similar to a previous one in Buffalo, N. Y.*

The processes at the plant consisted of the unloading and storage of barley in the elevator, cleaning and malting of the barley and the drying and cleaning, storing and shipping of the malted grain. The explosion occurred in the section known as the cleaning house shortly after the fire department reached the plant in response to a telephone call made by an employee, who discovered fire around a motor driving one of the malt cleaners.

The employee who discovered the fire had arrived at the plant shortly before 7 A. M. and started the blowers, then the malt cleaners, then the elevator leg handling malt, then the conveyor leading to the boot of this leg, and finally opened the malt hoppers, which permitted the malt to flow through the equipment mentioned to the storage bins. After starting the equipment and seeing that the malt was flowing satisfactorily, the employee was proceeding on the man-lift to the top of the house to open windows when he noticed the fire in and around one of the motors on the cleaner floor. He endeavored to extinguish it with small first aid extinguishers, but it was beyond his control and he called the fire department. The fire department report indicates that the firemen had directed a stream of water into the first floor and had stretched hose to the seat of the fire, but had not turned on the water at that point, when the explosion occurred.

The explosion was severe enough to lift the concrete floor over two of the bins and to rip open one side of a metal bin hopper. A number of wired glass windows were blown out with their frames, one of them a distance of about 30 feet, and some of the corrugated metal siding on the conveyor gallery leading to the storage tanks was blown off.

Undoubtedly the explosion was due to ignition of a dust cloud by the fire, which started in or around the cleaner motor.

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*"Buffalo, N. Y., Malt Dust Explosion," by David J. Price, N.F.P.A. QUARTERLY, July, 1934, Vol. 28, No. 1.

Grain Dust Explosion in Feed Mill.

Nashville, Tenn.

During the afternoon of June 19, 1934, a dust explosion occurred at the Ralston Purina Mill in Nashville, Tenn. Only the elevator section was in operation at the time and most of the employees were out of the building. No one was injured, but the explosion caused considerable property damage. There was also some fire and water damage when the flash spread through the building and opened 75 sprinkler heads. A ¾-inch sprinkler pipe was broken. The property loss will probably amount to about $10,000.

Story of Explosion.

The section of the plant in which the explosion occurred is of reinforced concrete construction about 50 x 100 feet and 170 feet high. It contains 41 bins, which are served by six steel elevator legs and conveyors. There is the usual installation of garners and scales and cleaning machinery. In addition there is an attrition mill on the second floor. The six steel elevator legs are grouped in a row across the building about 30 feet from the west wall. The explosion centered around these legs and spread into adjoining bins, where the pressure became sufficiently high to lift the concrete bin floor which serves as a cover for all bins. There is, however, a vent opening between inner and outer bins directly below the floor.

The explosion shattered the floor over at least six of the bins and cracked some of the bin walls. Four of the steel elevator legs were affected and in many places the steel housing was ripped open. The path of travel appears to have been upward from about the second floor level and undoubtedly would have been very severe on the upper floors if this part of the plant had not been clean and well vented. All windows in the upper part of the house were open and the elevator heads were vented through the roof. These openings allowed the pressure to vent itself and the absence of dust accumulations prevented a secondary explosion on the upper floors. The vented elevator heads were bulged, but did not burst.

Three operations were being carried on at the time the explosion occurred and naturally the cause of the explosion is assumed to have been associated with one of the three. A car of corn was being unloaded, oats were being transferred and cotton seed cake was being ground in the attrition mill. Several men had just left the bin floor a moment before the explosion occurred and the last man had just closed the fire door on the passenger elevator shaft and was starting the car when pieces of concrete were thrown against the door. No trouble of any kind was noticed or reported by these men. Another employee was near the attrition mill on the second floor, when suddenly flame shot out of the elevator legs and pieces of concrete fell all around him. Fortunately he was not injured.

Interior view of Ralston Purina Mill, Nashville, Tenn., showing damaged wall of bin adjoining elevator leg well.

The three operations mentioned above were as follows:

Corn was being unloaded from a railroad car on the track along the west side of the building. It passed through the unloading hopper on to a conveyor belt, up leg No. 3, and then by conveyor belt and tripper to a bin.

Oats were being transferred from a bin into and up leg No. 4, and through the scales into a spout, which carried them to the mill.

Cotton seed cake being ground on the attrition mill passed into leg No. 6, where it was elevated and transferred to a working bin.

Cause of the Explosion.

Both company and insurance investigators are of the opinion that the explosion did not start in the cotton seed leg, nor in the leg elevating corn. It is pointed out that none of the bins from which or to which the cotton seed meal and corn were being moved were directly affected and that the center

of damage was in and adjacent to the leg through which oats were being moved.

Foreign material in the oats could have caused a spark in the elevator boot and the flash could have communicated to the other legs and adjacent bins, but because recleaned oats were being handled, it is considered more likely that the spark which ignited the dust was produced when an elevator bucket scraped against the leg wall.

The damage to the legs made it difficult to determine the exact point of origin of the explosion.

Conclusions.

The value of cleanliness was again demonstrated because it is generally admitted that had the upper part of the plant not been free of dust a secondary explosion with considerable violence and extensive damage would have occurred.

Large windows or venting areas are necessary to release explosion pressures and prevent structural damage. In this case there was sufficient venting area in the form of open windows on the bin floor and elevator head vents through the roof to release the pressure of the explosion before any damage occurred to building walls.

Dust Explosion in a Country Elevator.

Tracy, Minnesota.

On June 22, 1934, a dust explosion occurred in the plant of the Farmers' Coöperative Elevator Company at Tracy, Minn. Four men were burned by the flash, but there was no property damage. The plant had a capacity of 14,000 bushels for grain storage and handling and facilities for feed grinding. It was during the operation of the feed grinder that the explosion occurred. The fact that little or no property damage resulted was probably due to the large venting area in the vicinity of the original ignition and the fact that the plant was in a clean condition.

The equipment used for feed grinding consisted of a motor driven attrition mill, with a scalper and magnetic separator ahead of the mill to catch foreign material. The mill discharged into an elevator leg which carried the feed up to a bin above the sacking spout. An inspection door on the front of the elevator leg was held in place by a hook.

Oats were being ground in the attrition mill at the time the explosion occurred. An employee was sacking the feed as it was ground and three farmers were standing near by. Suddenly an explosion blew off the inspection door on the elevator leg and the flash from this opening burned all of the men grouped on the work floor. Their faces and hands were severely burned and their clothing scorched. No fire followed the explosion except the ignition of

a few feed sacks near the packer. Woodwork was not even scorched and the equipment was undamaged. Operations were resumed later in the afternoon.

It was difficult to determine the cause of this explosion because the mill had been running satisfactorily for a good part of the day. On this particular run it had been started about 1:30 P.M., or an hour and twenty minutes before the explosion. The scalper and magnetic separator ahead of the mill should have removed much of the foreign material from the grain entering the mill. It is quite possible, however, that a stone or some non-magnetic material passed along with the grain and entered the mill. Contact between such material and the rapidly revolving plates of the mill is believed to have produced the spark which ignited the dust. It is also possible that some heavy piece of metal passed over the magnetic separator without being caught and produced sparks when it entered the mill.

Lessons from the Explosion.

This explosion emphasizes the value of two of the recommendations for dust explosion prevention. The first is the value of venting such as was provided by the wide open doors on the work floor of the plant near where the attrition mill was located, and the second is cleanliness. The Department has recommended the provision of venting area in the ratio of 1 sq. ft. for each 80 cu. ft. to release grain dust explosion pressures in cubical structures.* In this case the open doors undoubtedly permitted the release of the explosion pressures before they increased sufficiently to cause structural damage. Cleanliness undoubtedly prevented the explosion from spreading to other sections of the plant and was also responsible for the fact that no fire followed.

A study of this explosion suggests the desirability of providing, if possible, direct vents from the grinding mill to the outside of the building. With an opening direct to the outside from the mill housing or an inclosure directly beneath it an explosion originating in the mill could be released to the outside before sufficient pressure could be built up to force open doors or wreck equipment inside the building.

To provide maximum protection in grinding operations the use of inert gas is recommended. It has been demonstrated that dust ignitions in grinding equipment can be prevented when it is possible to use an inert gas such as carbon dioxide or nitrogen to dilute the oxygen within the mill to the point where it will not support combustion. In some cases it has been possible to use flue gas from the boiler of a near-by power house to produce the inert atmosphere within the grinding mill.**

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*"Venting Dust Explosions," Brown and Hanson, QUARTERLY, April 1933.

**"The Value of Inert Gas as a Preventive of Dust Explosions in Grinding Equipment," by Hylton R. Brown, U. S. Dept. of Agriculture, Technical Bulletin No. 74.

N.F.P.A. Safety Code for the Use of Inert Gas for Fire and Explosion Prevention.

A Cocoa Dust Explosion.

Chicago, Illinois.

An explosion of cocoa dust occurred at the Warfield Chocolate Company's plant, Chicago, Illinois, about 3:30 A.M., Thursday, July 12, 1934. The explosion, which was confined principally to the fourth floor, resulted in the death from burns of three employees, and injuries to three others, two of whom were seriously burned. The property damage was $15,000.

The building in which the explosion occurred is a seven-story brick structure, divided into three sections by fire walls. All ceilings are of the open-mill type. It was occupied by the Thomson and Taylor Company for the processing of tea, coffee, spices and extracts; and its subsidiary, the Warfield Chocolate Company, for the manufacture of chocolate and cocoa.

The fourth floor of sections B and C (see diagram) was divided into several refrigerator rooms by five-inch insulated partitions, consisting of three inches of compressed cork with one inch of plaster on both sides of the cork. Openings in the refrigerator rooms were provided with refrigerator-type doors and windows. The sheet metal ducts used for cooling these rooms were located near the ceiling.

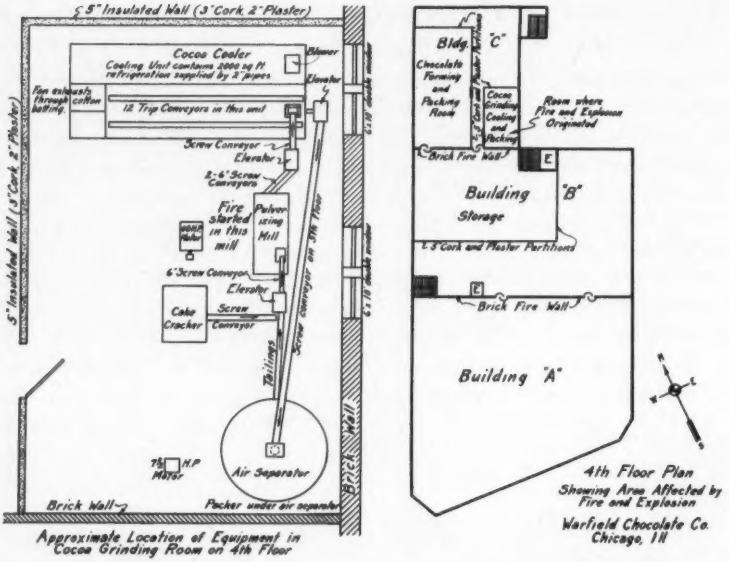
The raw cocoa beans are passed through an air separator to remove heavy foreign material and then roasted and cooled. The beans are fed through a breaker and fanner which removes the shell and chaff and leaves the meat or nibs. The nibs are passed over a magnetic separator and then ground in a processing mill or a burr mill to a semi-liquid state. This product is called cocoa liquor. The cocoa butter is expressed by means of hydraulic presses and the cocoa cake placed in cold storage for several days. The cake is passed through a cake breaker, then through a pulverizer and the resulting product is conveyed through a cocoa cooler. The ground cocoa is passed through an air separator where the coarse material is removed and returned to the pulverizer while the finished product is packed in barrels and small packages. From the time the cocoa cake leaves the press room, all storage and processing is done in refrigerated rooms.

Story of the Explosion.

About 2:30 A.M. July 12, 1934, the night watchman stopped at the cocoa grinding room on the fourth floor of Section "C" (see fourth floor plan) and found the night superintendent, the operator of the cocoa grinding room, and his helper cleaning the pulverizer. The night superintendent told the watchman that there had been a fire in the pulverizer and that they were cleaning it out so that operations could be resumed.

The cocoa grinder's report showed that the pulverizer had been shut down at 1:30 A.M., and that it had been started again at 3:00 A.M.

At 3:30 A. M. the watchman, who was on the first floor, heard an explosion. He started up the west stairs in section "B" and met two employees,



who were severely burned, coming down. He helped to remove their burning clothes and had them taken to Mercy Hospital. At 3:32 an employee of the Cuneo Press, located across the south branch of the Chicago River, saw the fire and sent in an alarm from a city fire alarm near his building.

In the meantime three employees, all of whom were severely burned, came down the north central stairs in section "B" to the press room in the basement. Their burning clothes were removed and they were taken to St. Luke's Hospital. A sixth employee, suffering from shock and injuries sustained from a fall, came down the stairs at the northeast corner of section "C." He also was taken to a hospital.

It is known definitely that the night superintendent, the cocoa grinder and his helper, all of whom died from burns, were in the cocoa grinding room at the time of the explosion. Another employee, who was seriously burned, was in Section "B" near the fire door, adjacent to the cocoa grinding room. The fifth man, who was also badly burned, was in the chocolate packing room across the hallway from the cocoa grinding room. Two chocolate packers who were working in the chocolate packing room, were not injured and escaped through a blown-down partition. An employee who was working on a chocolate bar molding machine at the northwest corner of the fourth floor in Section "C" likewise escaped uninjured.

The cocoa grinder died at 1:30 P.M. July 12, the night superintendent at 11:00 P.M. the same day, and the cocoa grinder's helper on July 19. On July 21 three of the injured men were still in the hospital and the condition of two of them was regarded as serious.

The explosion blew out the five-inch insulated wall around the cocoa-grinding room. Two large double windows were blown out. These windows were of the type commonly used in refrigeration rooms and consisted of three windows with air spaces between them. The insulated wall across the hallways was blown out toward the cocoa-grinding room. A section of a similar wall in Section "B" also was blown out, and a heavy beam to which the wall was attached and supporting the floor above, was moved from two to six inches. The explosion evidently propagated from the fourth floor to the fifth through a small opening between the air separator and the fifth floor, and while no damage was done by the explosion on the fifth floor, some damage was done by the fire which followed. The fire that followed the explosion was quickly extinguished by thirty sprinkler heads, together with two hose lines brought in from the outside. Several small fires opened three sprinkler heads on the third floor of Section "C."

The wooden frame around the cocoa cooler was almost completely destroyed by the explosion and fire. The inside portion was badly charred, which indicated that there had been a fire in the cooler, and there was considerable evidence, such as twisted hinges on the door frames, that indicated an explosion had occurred in the cooler. The elevator legs were not damaged and showed little if any indication of flame propagating through them. The air separator was not damaged and there was no indication of fire inside of it. The air ducts used in the refrigeration system were not damaged, although it seems possible that the explosion did propagate to the chocolate packing room across the hallway through the ducts interconnecting these rooms.

Cause of Fire and Explosion.

It has been definitely established that there was a fire in the cocoa pulverizer before the explosion occurred. While such fires do not occur frequently, it is known that they do cause trouble at irregular intervals over long periods of time.

Foreign materials, such as nails, could enter the mill and produce sparks that may ignite the cocoa. The burning or smouldering cocoa could pass through the pulverizer before enough heat was generated to cause a large mass of the cocoa to become plastic, and thus prevent additional material from passing through. In this manner fire could be conveyed to the cocoa cooler and other equipment. It is known that foreign material was found sometimes in the mill and it seemed quite probable that it was responsible for the fire that preceded the explosion.

It is believed that the fire which originated in the pulverizer was conveyed to the cocoa cooler and continued to burn in the cooler after the pulverizer had been shut down. What was left of the woodwork of the cooler was deeply charred on the inside, which showed that a fire had burned in it for a considerable time. The explosion is believed to have originated in the cocoa cooler when a dust cloud of sufficient concentration to propagate flame came in contact with the burning material in the cooler.

It is believed that the initial explosion in the cocoa cooler blew out the walls of the cooler and ignited a dust cloud in the grinding room, which blew out the windows and insulated partitions of the grinding room, and some of the insulated partitions of the chocolate packing room across the hallway from the grinding room, and a similar partition in Section "B."

Recommendations.

1. All machines and conveyor systems should be kept tight wherever practicable to prevent the escape of dust.

2. The modern type of barrel packer will eliminate much of the dust in barrel packing operations.

3. Hoods provided with suction and connected to a dust collector outside of the building should be placed over all points where dust cannot be prevented from escaping.

4. A regular and frequent clean-up schedule should be maintained.

5. A self-cleaning magnetic separator should be placed so that all material delivered to the pulverizer will pass over the separator.

6. Automatic sprinklers should be installed in cocoa coolers.

7. An automatic, carbon dioxide gas fire protection system is recommended for pulverizers, cocoa coolers, air separators and elevator legs.

8. Refrigerator type windows in air conditioned rooms should be hinged from the top so that they will be readily blown open by an explosion.

9. All electrical equipment should be of approved dust-tight type and should be preferably located outside the pulverizing room. Electric lights should be fitted with dustproof globes and strong metal guards.

10. Screw conveyors from the pulverizers to the cocoa coolers should be provided with chokes by substituting pins for a small portion of the blade.

11. In case of fire in pulverizers the grinding room should be shut down and should not be started until a responsible person is absolutely sure that all fire is extinguished. The safest plan is to call the fire department.

Department Store Fire Record.

Since the publication of the Mercantile Fire Record in the QUARTERLY for October, 1932 (Vol. 26, No. 2), the N.F.P.A. Department of Fire Record has received numerous requests for a similar record, covering department stores. It is in response to these requests that this present record has been prepared.

The potential hazards of department stores, including large chain stores handling a wide variety of merchandise, differ markedly from the general mercantile class. The typical department store includes under one roof or in a single establishment large stocks of varying kinds of merchandise, much of it highly combustible, with special hazards such as restaurants, kitchens, and other departments involving special fire protection consideration. For the most part, such stores represent a better grade of management and maintenance. Private fire protection facilities are more adequately provided and better cared for, and greater stress is laid upon the importance of fire prevention.

In making up the accompanying statistical data, reports of fires occurring within the period from January 1, 1913, to July 1, 1934, have been included. A total of 1266 reports have been analyzed and tabulated so as to form tables which, for the most part, coincide with similar tables published in the mercantile fire record. Two changes may be noted, however. The table showing the analysis of losses has been amplified by the addition of more detailed classifications and a table has been prepared to show how the fires were discovered. A number of fires occurring in small department stores in buildings occupied by various types of occupancy and where more than one occupancy has been involved are classified by the Department of Fire Record as "Multiple Occupancies." Due to difficulties incidental to so doing, these fires have not been included as part of the present mercantile fire record.

Although this record includes a representative number of small fires involving sprinklered property, the number of small fires in non-sprinklered buildings seems obviously out of proportion to the total number of fires in such property. This is probably due to the fact that insurance inspection bureau reports are the source of data on the majority of the fires in the record, and while reports of fires in *sprinklered* property are ordinarily filed with the N.F.P.A. Department of Fire Record regardless of the size of the loss, many reports of small fires in department stores in small communities and not under sprinkler protection are not so filed.

In view of the character of the original data, which include most of the larger and more important fires but not a fair proportion of the smaller fires,

Five buildings, comprising a department store, were gutted by this fire at Lowell, Mass. This fire demonstrated not only the need of automatic sprinkler protection, especially in a building of inferior construction, but the desirability of standard cut-offs between buildings.

this record may not be completely representative. The record, however, includes a sufficiently broad selection of the important department store fires so that there can be no question as to the validity of conclusions drawn from the tables.

The following table shows the distribution of causes of fires in department stores. It is interesting to note that in relative importance the various causes, with one exception, follow closely those tabulated for other mercantile properties.

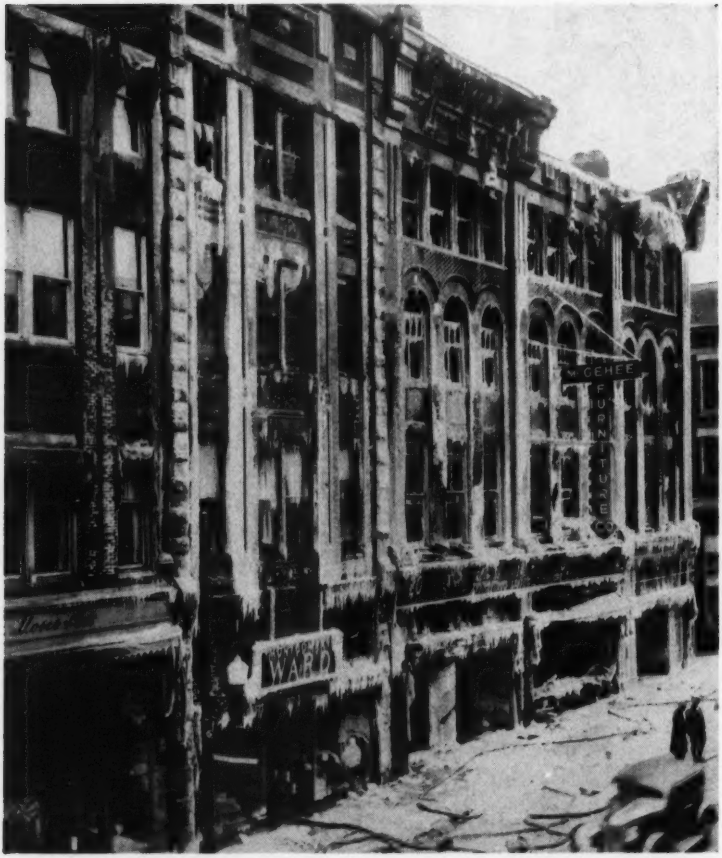
Classification of Causes.

Cause		No. of Fires	Per Cent of Known Causes
Matches—smoking		236	26.0
Electric causes		182	20.0
Ignition of rubbish or litter (See also spontaneous ignition)*		147	16.2
Probably from careless smoking	60		
By sparks from boiler or incinerator	39		
From unknown cause	48		
Spontaneous ignition		93	10.2
Oily material	52		
Rubbish or litter	32		
Miscellaneous	9		
Exposure		47	5.2
Ignition of fat or grease on stove or in vent		41	4.5
Defective or overheated heating equipment		27	2.9
Defective or overheated stoves or furnaces	16		
Defective oil burning equipment	11		
Electric iron left on		22	2.4
Other known causes (less than 20 fires from each)		114	12.6
Total known causes		909	100.0
Unknown		357	
Total		1266	

The careless disposition of matches and smokers' materials is responsible for the greatest number of fires of known origin in department stores. The per cent of fires from this cause is approximately five per cent greater than in the case of general mercantile occupancies. It is significant that eighty-nine of the 236 fires attributed to this cause occurred in waste paper chutes or vaults, twenty-seven in storerooms or stockrooms, and fifteen in shipping or receiving rooms. Only twenty-five fires originated in salesrooms available to the public. The hazard of smoking would seem, therefore, to be chargeable to the failure of employees to observe "no smoking" regulations rather than to thoughtlessness or carelessness on the part of store visitors.

*While commonly referred to as a fire cause, "Rubbish" of itself is not a cause of fires but is classed as such because rubbish accumulations so often furnish the fuel necessary for the starting of fires by the careless disposition of cigarettes or matches, and sparks from various sources.

tween buildings.



Fire originating in the furniture store at the right of the picture communicated to the department store in the center through sub-standard party walls with sub-standard parapets. "Exposure" as a fire cause was responsible for five per cent of all department stores in this record.

Electrical causes claim their usual share of fires, with defective wiring and short circuits indicated as the major factors. Thirty-five fires of electrical origin occurred in salesrooms and thirty in show windows, a very considerable portion of which may be directly charged to improperly installed and inadequately safeguarded temporary wiring. Defects in connection with Christmas tree wiring were responsible for a number of fires as was the operation of toy electric trains in show windows or on display counters.

The ignition of rubbish or litter accounts for 179 fires or approximately 20 per cent of the total of known origin. Sixty of these were chargeable to the

International.

An inaccessible and unsprinklered space beneath the grade floor of this Birmingham, Ala., sprinklered department store and a delay in calling the fire department were primary factors in this fire, which totally destroyed the building and its contents and seriously damaged surrounding property.

careless disposition of smokers' materials, thirty-nine to sparks from boilers or incinerators, thirty-two to spontaneous ignition, and in forty-eight instances the source of ignition was not stated. Approximately half of these fires were in waste paper chutes or in rooms given over to the disposal of waste paper. As for other sections of the store good housekeeping is a primary requisite of fire safety and no excuse exists for the store whose basement and under-counter spaces are choked with packing material and floor sweepings.

Little need be said of oily material as a fire hazard. Its presence in department stores seems unjustified, and fires from this cause may well be regarded as strictly preventable.

In kitchens operated in conjunction with department store restaurants, fires due to the ignition of grease on stoves or in vents therefrom predominate. Most of these grease fires were entirely due to carelessness in permitting fat or grease to boil over during cooking operations.

The analysis of losses which have occurred in department stores indicates that 70 per cent of the 1266 fires involved losses reported as small or less than $5000. This compares with 54.6 per cent for general mercantile occupancies. Superior construction, automatic sprinklers and greater fire prevention efforts on the part of large department store organizations are without doubt impor-

International.

Defective construction and the absence of automatic sprinkler protection permitted this fire, originating in the basement of a Flushing, L. I., department store, to extend upward by means of pipe recesses and boxed columns. Practically everything in the store was damaged by fire. The roof was burned off.

tant factors in this better record. It is significant, too, that practically all of the 271 fires which occurred in waste paper rooms or chutes were extinguished with but small loss, due to the prompt operation of sprinklers which had been installed in these hazardous locations.

Analysis of Loss.*

	Sprinklered		Unsprinklered		Total	
	Fires	Per Cent	Fires	Per Cent	Fires	Per Cent
Small loss	842	88.0	45	14.6	887	70.0
Moderate to considerable loss	105	10.9	117	38.0	222	17.5
Large loss	10	1.0	141	46.0	151	12.0
No data as to loss	1	.1	5	1.6	6	.5
Total Fires	958	100.0	308	100.0	1266	100.0

*Small loss fires for the purposes of this table are those reported as "small," "slight" or less than $5000. Moderate to considerable losses are those so reported, or involving losses from $5001 to $50,000. Large losses are those reported as "large" or "heavy" or in excess of $50,000.

The value of automatic sprinkler systems in department stores is shown by the fact that 88 per cent of the fires in sprinklered buildings were recorded as small loss fires and that in approximately 98 per cent of the 746 fires in which sprinklers operated, the sprinklers either extinguished the fire completely or held it in check.

Effect of Sprinklers.

	Wet System	Per Cent	Dry System	Per Cent	No Data	Total	Per Cent
Extinguished Fire	533	79.6	43	79.7	15	591	79.2
Held Fire in Check	129	19.2	8	14.8	5	142	19.1
Total Satisfactory	662	98.8	51	94.5	19	733	98.3
Unsatisfactory	8	1.2	3	5.5	2	13	1.7
Total	670	100.0	54	100.0	22	746	100.0

Sprinkler Fire Record.

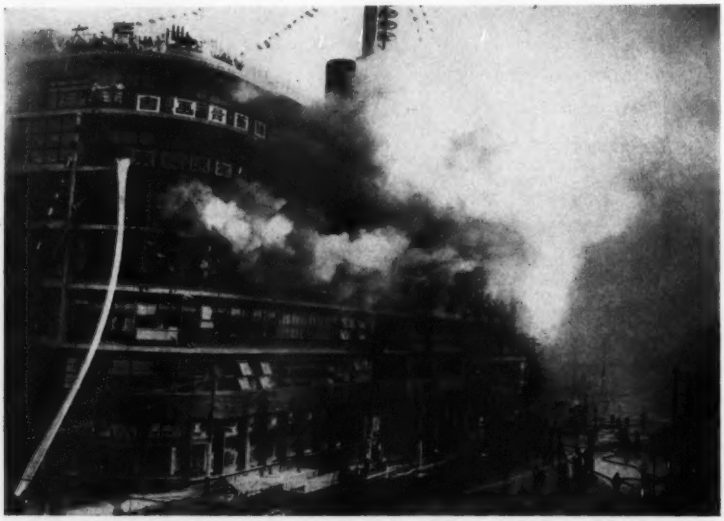
No. of Heads Opening	Number of Fires. Wet	Per Cent	Dry	Per Cent	No Data	Total	Per Cent
1	373	55.7	11	20.4	8	392	52.6
2	168	25.1	9	16.7	7	184	24.6
3	54	8.0	4	7.4	0	58	7.8
4	34	5.1	3	5.5	2	39	5.2
5	12	1.8	8	14.8	0	20	2.7
6-9	11	1.6	2	3.7	0	13	1.7
10-25	10	1.5	7	13.0	1	18	2.4
26-50	2	.3	0	.0	1	3	.4
Over 50	6	.9	3	5.5	2	11	1.5
No data	0	.0	0	.0	1	1	.1
Open head systems	0	.0	7	13.0	0	7	1.0
Total	670	100.0	54	100.0	22	746	100.0

Complete data as to the method of discovery of the fires in the record were not available. However, it has been possible to make a general summary as indicated by the table which follows.

Method of Discovery	Losses Under $10,000	Losses Over $10,000	Total Fires
Outsider	59	169	228
Employee	402	68	470
Watchman	121	16	137
Sprinkler bell or gong	103	2	105
Sprinkler supervisory	198	5	203
Watchman heard sprinkler bell	19	0	19
Thermostats or automatic alarm	18	3	21
Thermostats and sprinkler supervisory	3	0	3
Total, known discovery	923	263	1186
No data as to discovery	50	30	80
Total	973	293	1266

Point of Origin of Fires.

	No. of Fires	Per Cent of Total of Known Origin
Waste paper and rubbish room or chute	271	23.5
Basement (fires not otherwise classed)	129	11.2
Salesrooms	117	10.2
Stock and storage rooms	105	9.1
Boiler or engine room	70	6.1
Receiving or shipping rooms	61	5.3
Restaurant or kitchen	59	5.1
Outside—exposure	47	4.1
Workroom or shop	44	3.8
Elevator shaft or motor room	44	3.8
Show window	43	3.7
Hallway, corridors or stairways	19	1.6
Office	17	1.5
Locker room	12	1.1
Roof	11	1.0
Miscellaneous	103	8.9
Total of known point of origin	1152	100.0
No data as to point of origin	114	
Total Fires	1266	



Although this Tokyo, Japan, department store was of fire-resistive construction, a fire, originating from an electrical short circuit in a Christmas tree and fed by the highly combustible contents of the room, swept the interior of the building, with a resultant loss of 14 lives, injuries to approximately 100 persons, and property damage amounting to $2,000,000. Automatic sprinklers would, in all probability, have held the fire to the point of origin.

Fires in Which There Was Loss of Life.

Third Quarter, 1934.

Since the publication of the July QUARTERLY, the N.F.P.A. Department of Fire Record has received from various sources 126 reports of fires in which there has been loss of life. A total of 364 lives were lost in these fires, including the 124 fatalities incident to the burning of the steamship *Morro Castle*, a report of which appears on page 113 of this QUARTERLY. Other disasters involving a loss of more than ten lives have occurred during this period as follows:

JULY 22, 1934. OSSINING, N. Y. Nineteen persons lost their lives and a number of others were seriously burned when a bus plunged down an embankment and burst into flames. A number of the victims were trapped in the wreckage and burned to death, while others died later in hospitals after being extricated. The bus was of an obsolete type and defective brakes are blamed for the accident.

AUGUST 6, 1934. BIG STONE GAP, VA. Seventeen miners were trapped and lost their lives and five others were injured when an explosion followed by fire occurred in the mine. The cause of the explosion is unknown.

Loss of Life Fires, July-September, 1934.

This is a typical rather than a complete record, presented to show the conditions under which loss of life occurs, that they may be known and guarded against. The total loss of life by fire in the United States is estimated at 10,000 annually.

Class of Fire	No. Fires	Men	Women	Children	Total
Airplane	7	12	2	0	14
Apartments, hotels, lodgings, tenements, etc.	5	3	8	0	11
Automobile fires	14	30	12	3	45
Barns and stables	5	2	0	5	7
Camping tent	1	0	0	2	2
Conflagrations	2	2	1	0	3
Dwellings—Rural	19	7	9	23	39
Dwellings—Urban	22	7	7	6	20
Dynamite factory	1	9	1	1	11
Forest or brush	4	5	0	0	5
Gasoline distributing station	2	8	0	0	8
Industrial occupancies	13	20	0	0	20
Institutions	2	0	1	1	2
Lumber yard	1	1	0	0	1
Mining property	1	17	0	0	17
Oil refineries	1	1	0	0	1
Other buildings	4	2	0	2	4
Outside buildings	12	5	0	9	14
Railroad property	4	5	0	2	7
Response to alarms	1	2	0	0	2
Ships and boats	2	78	43	4	125
Tank ships and barges	2	5	0	0	5
No data	1	1	0	0	1
Total	126	222	84	58	364

Causes of Loss of Life, July-September, 1934.

Fatalities classified according to the immediate cause of the loss of life rather than according to the cause of the fire.

Causes	Men	Women	Children	Total
Airplane fires	12	2	0	14
Automobile fires	30	12	3	45
Children and matches	0	0	10	10
Chemicals and explosives:				
Chemical laboratory	4	0	0	4
Dynamite factory	9	1	1	11
Clothing ignited:				
Boiling wax	1	0	0	1
Bonfire	0	0	2	2
Incinerator	1	0	0	1
Pyroxylin comb	0	0	1	1
Starting incendiary fire	1	0	0	1
Stove	0	2	0	2
Dust explosion:				
Cocoa dust	3	0	0	3
Wood dust	1	0	0	1
Entering burning buildings	0	0	2	2
Explosions (miscellaneous):				
City gas	0	2	0	2
Paper coating plant (secret process)	1	0	0	1
Unknown on motorboat	1	0	0	1
Unknown	1	4	0	5
Fireworks	0	0	4	4
Fire fighting	3	1	0	4
Flammable liquids or vapor:				
Alcohol in bottle	1	0	0	1
Benzine mistaken for bleaching fluid	0	2	0	2
Gasoline distributing station	8	0	0	8
Gasoline in tractor tank	0	0	1	1
Gasoline railway motor car	2	0	0	2
Gasoline stove	1	0	0	1
Gasoline used for exterminating	1	1	0	2
Gasoline used to start fire	1	1	6	8
Gasoline tank "empty" being soldered	1	0	0	1
Gasoline vapor ignited by match	0	1	0	1
Kerosene spilled on clothing	0	1	0	1
Kerosene stove	0	0	3	3
Kerosene used to start fire	0	2	1	3
Naphthalene tank	4	0	0	4
Naphtha or gasoline in tank car	2	0	2	4
Oil explosion at gas compressing plant	1	0	0	1
Oil refinery	1	0	0	1
Paint filler vapors	0	0	1	1
Rubber cement mixed with benzine	1	0	0	1
Tank ship or barge	5	0	0	5
Forest fire fighting	5	0	0	5
Mine fires and explosions	17	0	0	17
Overcome by smoke—suffocation	0	0	1	1
Railroad accidents	2	0	0	2
Response to alarms	2	0	0	2
Ship disaster	77	43	4	124
Smoking in bed	1	2	0	3
Trapped in burning buildings	20	7	14	41
Trapped in burning tent	0	0	2	2
No data	1	0	0	1
Total	222	84	58	364

Two disasters of interest have occurred outside of the United States and Canada during the period covered by this record. Eleven persons, including eight passengers, lost their lives when an airplane crashed and burst into flames near Lake Constance, Germany, on July 27, 1934. At Ensisheim, France, on August 13, 1934, eight men were killed and three were injured by a series of explosions in a potash mine. The mine was not in operation at the time of the explosion and the victims were engaged in repairing an elevator cable.

It should be noted that the cause table has been revised from its customary form by the inclusion of new major headings such as "Chemicals and explosives," "Dust explosions," and "Flammable liquids and vapors." It is believed that this arrangement will be more specific than the former method of grouping together all explosions and flash fires regardless of their origin.

Typical Loss of Life Fires.

Children and Matches.

L-2655. BOSTON, MASS., JUNE 20, 1934. A thirteen-month-old baby girl was burned to death when another little girl dropped a lighted match on the baby's dress.

L-2656. MONTREAL, QUEBEC, JULY 8, 1934. A two and a half-year-old boy died in a hospital of burns suffered while playing with matches near his home. Another child was holding a comb, which caught fire from a lighted match and set fire to the victim's clothing.

L-2657. EAST BRIDGEWATER, MASS., AUGUST 7, 1934. A five-year-old boy was burned to death while playing with matches in a barn near his home. The matches ignited hay and his clothing caught fire. A neighbor saw smoke coming from the building, but the child was fatally burned before aid could reach him.

L-2658. MONTREAL, QUEBEC, AUGUST 19, 1934. An eight-year-old girl was severely burned and died three days later in a hospital when her clothing ignited as she was playing with matches in a shed.

L-2641. GUILFORD, VT., AUGUST 26, 1934. Two little girls aged two and three, were fatally burned while playing in a barn when their four-year-old brother set fire to the structure while playing with matches. Their mother was badly burned in carrying out one of the little victims.

Entering Burning Building.

L-2659. WILLIAMSON, N. Y., AUGUST 3, 1934. Two five-year-old boys, chums, were burned to death when they ran into a burning farm barn to save a litter of kittens. The mother of one of the boys reached the scene in time to save her two-year-old daughter who was playing with the boys. One of the boys' bodies was found near the door with a kitten under each arm.

Fireworks.

L-2660. WASHINGTON, D. C., JUNE 27, 1934. A seven-year-old boy was fatally burned when his clothing ignited following the explosion of a home-made fireworks "bomb" in the basement of his home. The victim and his brother had obtained the powder for the "bomb" from a firecracker. Fireworks are illegal in this city.

L-2661. NEW YORK, N. Y., JULY 4, 1934. A seven-year-old girl was fatally burned and died in a hospital when her clothing was ignited by an exploding firecracker.

L-2662. QUINCY, MASS., JULY 4, 1934. A seven-year-old girl succumbed to burns and shock when a sparkler she was holding ignited her clothing. She died shortly after being taken to a hospital.

Benzine Mistaken for Bleaching Fluid.

L-2653. WATERBURY, CONN., JULY 27, 1934. Two women lost their lives when they used benzine mistaken for bleaching fluid in cleaning an electric washing machine. Vapor from the benzine ignited when one of the women turned on the switch to operate the drain pump.

Gasoline Used for Exterminating.

L-2663. ATLANTA, GA., JUNE 15, 1934. A woman hired a negro to spray her basement with gasoline to exterminate insects. A short time later the woman went into the basement and struck a match to light a water heater. The gasoline vapor exploded, blowing out a portion of the brick foundation of the house and enveloping the woman in flames, and she was fatally burned.

L-2664. HAVERSTRAW, N. Y., JULY 19, 1934. A man was exterminating snails in the basement of his home, using a can of gasoline in which he placed the snails as he found them. The vapor from the gasoline ignited and flashed, possibly from a lighted match. In his excitement the man kicked over the can of gasoline and his clothing ignited. His daughter smothered the flames on his clothing with blankets, but too late to save the victim's life.

Gasoline Used to Start Fire.

L-2665. ST. FRANCOIS, QUEBEC, JUNE 21, 1934. Two small boys were burned to death and their brother and father were seriously burned when the latter used gasoline which he mistook for kerosene to start a fire in the kitchen stove. The father was burned when he tried to beat out the flames on the children's clothing.

Gasoline Vapor Ignited.

L-2666. SOUTH HARWICH, ONT., JULY 7, 1934. A seven-year-old boy was fatally burned as he held a lighted lantern while his stepfather poured gasoline into a tractor tank. Gasoline vapor ignited and the boy was enveloped in flames and died the following day in a hospital.

NOFUZE "DE-ION" BREAKERS *make wiring protection* PERMANENT

Above—*Cutaway view of a Westinghouse "De-ion" Circuit Breaker similar to those used in the Panelboard shown below.*

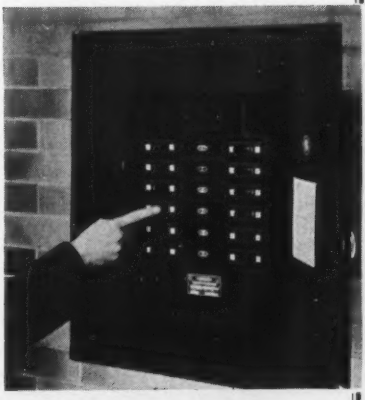
Below—*A Westinghouse Nofuze Panelboard. When a short circuit or heavy overload occurs, the breaker protecting that circuit automatically opens. After the overload is removed, and only then, service can be restored instantly by a mere flip of the breaker handle.*

THERE is nothing to burn out or replace when electrical circuits are protected by Westinghouse Nofuze devices. Their "De-ion" Circuit Breakers, which replace fuses, provide *permanent, certain* protection that is tamper-proof. They completely eliminate the hazards of blocking blown fuses with pennies, wires and other makeshift electrical conductors.

Protection is *permanent* because the "De-ion" Breakers are accurately calibrated at the factory, and *sealed* in a molded housing.

Protection is *certain* because the breaker trips free from its handle when interrupting the circuit under harmful overload conditions. No one can hold it closed, or block its opening action.

"De-ion" breakers are used on Westinghouse Nofuze Load Centers and Panelboards for homes and buildings, and on Nofuze Circuit Breakers for industrial applications. *They are approved by the Underwriters' Laboratories.*



Westinghouse

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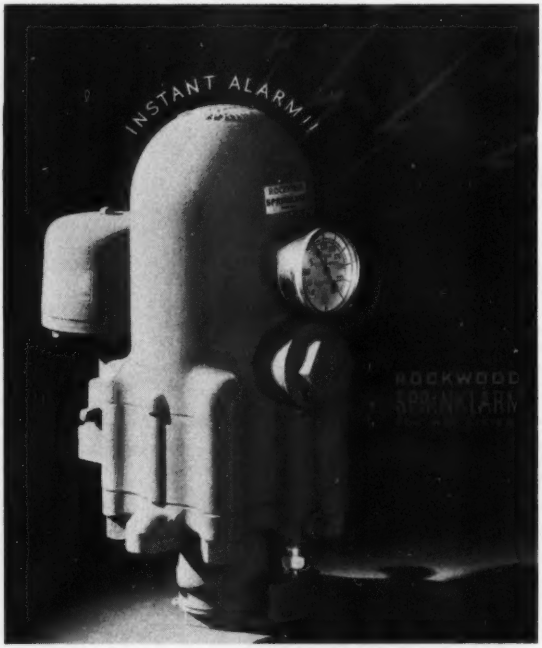


AS EFFICIENT AS THE SPRINKLER HEAD

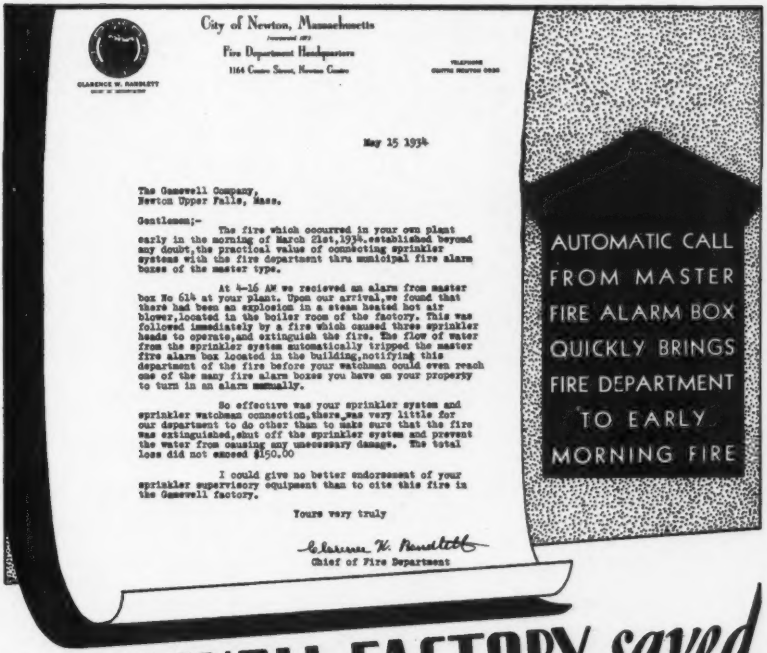
N.F.P.A. fire records for the past thirty-five years are an amazing story of the efficiency of the sprinkler head. Now — for the first time — the sprinkler alarm has been made as efficient as the sprinkler head.

ROCKWOOD SPRINKLARM operates on a drop in pressure rather than a flow of water. The alarm is quicker — false alarms are eliminated — signals are received even though water is shut off.

Why not specify Rockwood Systems and get the exclusive advantage of this tremendous improvement. Bulletin on request.

ROCKWOOD SPRINKLER COMPANY
Worcester, Mass.

WORCESTER FIRE EXTINGUISHER COMPANY
Canadian Company


City of Newton, Massachusetts
Fire Department Headquarters
1164 Centre Street, Newton Centre
CLARENCE W. RANDLETT
May 15 1934
The Gamewell Company,
Newton Upper Falls, Mass.
Gentlemen:-
The fire which occurred in your own plant early in the morning of March 21st, 1934, established beyond any doubt, the practical value of connecting sprinkler systems with the fire department thru municipal fire alarm boxes of the master type.
At 4-16 AM we recieved an alarm from master box No 614 at your plant. Upon our arrival, we found that there had been an explosion in a steam heated hot air blower, located in the boiler room of the factory. This was followed immediately by a fire which caused three sprinkler heads to operate, and extinguish the fire. The flow of water from the sprinkler system automatically tripped the master fire alarm box located in the building, notifying this department of the fire before your watchman could even reach one of the many fire alarm boxes you have on your property to turn in an alarm manually.
So effective was your sprinkler system and sprinkler watchman connection, there was very little for our department to do other than to make sure that the fire was extinguished, shut off the sprinkler system and prevent the water from causing any unnecessary damage. The total loss did not exceed $150.00
I could give no better endorsement of your sprinkler supervisory equipment than to cite this fire in the Gamewell factory.
Yours very truly
Clarence W. Randlett
Chief of Fire Department
AUTOMATIC CALL FROM MASTER FIRE ALARM BOX QUICKLY BRINGS FIRE DEPARTMENT TO EARLY MORNING FIRE

GAMEWELL FACTORY *saved* FROM HEAVY FIRE LOSS *—by OWN APPARATUS*

It wasn't necessary for us to have an explosion and fire in our own plant to convince us of the value of connecting sprinkler systems with the municipal fire department through a Gamewell master fire alarm box *(known as the Sprinkler Watchman)*. The service record of our *Sprinkler Watchman* hook-up in hundreds of other properties had convinced us of that.

Fire Chief Clarence W. Randlett of Newton, Mass., tells us in the above letter how our *Sprinkler Watchman* hook-up saved our own plant from a heavy loss. This is just one more case illustrating the value of a sprinkler system connected to the fire department through the dependable Gamewell master fire alarm box.

Every insurance company should encourage its sprinklered risks to install this Gamewell *Sprinkler Watchman* hook-up. It will save thousands of dollars in fire and water losses. Shall we send you literature?

THE GAMEWELL COMPANY

Newton, Massachusetts.

"A Box a Block"

FIRE PREVENTION

Those organizations and individuals who devote their time and their efforts to the reduction of the nation's tremendous annual fire waste, have set themselves a stupendous task, but one that is worthy of every effort expended. Fire prevention results in a saving of many lives and thousands of dollars worth of property.

For the benefit of property owners, the Automobile Insurance Company and The Standard Fire Insurance Company maintain in their Special Hazard Department, trained fire prevention engineers who make it their business to study the causes of fire losses and the means by which they may be prevented.

THE AUTOMOBILE INSURANCE COMPANY
THE STANDARD FIRE INSURANCE COMPANY
Of Hartford, Conn.

Affiliated with the Ætna Life Insurance Company

Ford Historical Exhibition and Museum, Century of Progress, Chicago, 1934.

Another Viking Achievement!

This building was completely sprinklered in 30 days. The entire Chicago Viking organization worked shoulder to shoulder with architect and contractor to the end that the sprinkler installation did not hold either back in the carrying out of their plans. Co-operation was the keynote of this outstanding achievement.

Regardless of the nature of the fire hazard, there's a Viking Automatic Sprinkler System that will afford fullest protection.

● Write for your free copy of this new fully illustrated Catalog, giving valuable information about automatic fire protection.

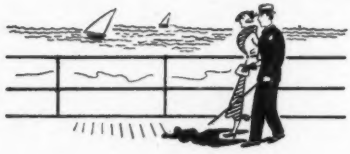
VIKING AUTOMATIC SPRINKLER SYSTEMS

VIKING COMPANIES:

Atlanta, Ga.-Charlotte, N. C.—Crawford & Slaten Co.
Boston, Mass.—Viking Automatic Sprinkler Co.
Buffalo-Syracuse, N. Y.—Viking Automatic Sprinklers, Inc.
Chicago, Ill.—Viking Automatic Sprinkler Co.
Cincinnati-Cleveland, Ohio—Viking Sprinkler Co.
Dallas-Houston, Texas—Texas Automatic Sprinkler Co.
Detroit, Mich.—Viking Sprinkler Co.
Grand Rapids, Mich.—Viking Automatic Sprinkler Co.
Huntington, W. Va.—C. W. Hutchinson, Inc.
Indianapolis, Indiana—Indiana Automatic Sprinkler Co.
Kansas City-St. Louis, Mo.—Walton-Viking Co.
Los Angeles-San Francisco, Cal.—Viking Automatic Sprinkler Co.
Minneapolis, Minn.—Viking Automatic Sprinkler Co.
New York, N. Y.—Viking Automatic Sprinklers, Inc.
Reading, Pa.—Viking Automatic Sprinkler Co.
Seattle, Wash.-Portland, Ore.—Viking Automatic Sprinkler Co.
Toronto, Ontario—Viking Automatic Sprinklers, Ltd.

THE VIKING CORPORATION
HASTINGS, MICHIGAN

VERY TRULY YOURS



At Chalfonte-Haddon Hall you are Sir Boss. Everything here; the cozy, quiet lounges and cheerful rooms, the Ocean Decks and modern health baths, the entertainments, superb food, friendly service, and countless little comforts — all exist distinctly for your amusement and repose. Even the beach is at our door, inviting you to a brisk canter beside the surf, a stroll in the mellow sunshine. If golf suits your mood, or a swift game of squash, here you may enjoy them to your heart's content. The Chalfonte-Haddon Hall squash courts are modern and fully equipped. • Autumn is a prime season by the sea. Bring the family down soon to this friendly, family hotel. The latch-string is always out at Chalfonte-Haddon Hall, and you'll never regret that you pulled it. Attractive rates. American and European plans.

LEEDS AND LIPPINCOTT COMPANY

Chalfonte-Haddon Hall

ATLANTIC CITY

EASTMAN

X-RAY FILMS

ARE NOW SUPPLIED ON SAFETY BASE EXCLUSIVELY

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BUT... Some hospitals and other institutions still have radiographs on nitrate-base film. In this connection the regulations of the National Board of Fire Underwriters for the Storage and Handling of Nitrocellulose Films state: "Where both kinds of film (nitrate and safety base) are used or stored at the same location in any building, the requirements for nitrocellulose film shall apply."

The Eastman Kodak Company is glad to cooperate in recommending suitable facilities conforming to this regulation.

All Eastman X-ray Films on safety base may be stored in the same manner as paper records.

●

EASTMAN KODAK COMPANY

ROCHESTER, NEW YORK

NRA CODE

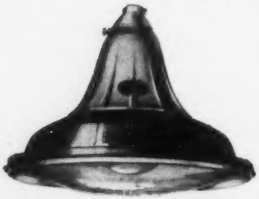
BENJAMIN LIGHTING FIXTURES

for HAZARDOUS LOCATIONS

200-Watt Explosion-Proof with Totally Enclosed Lamp and Reflector

BENJAMIN EXPLOSION-PROOF FIXTURES

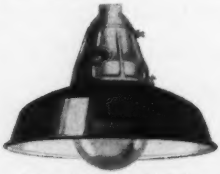
For installation in Class 1, Group D, Hazardous Locations—atmospheres containing the vapors of gasoline, common petroleum, ethyl alcohol, methyl alcohol, acetone and lacquer solvents. All parts of ample strength, designed to withstand internal explosions without breaking down or permitting flame to escape. For 200 watts, with totally enclosed lamp and reflector; for 100 and 150 watts, with lamp enclosed in a special heat resisting glass globe designed to withstand high internal pressures and with or without porcelain enameled steel reflectors. Benjamin Explosion-Proof Fixtures can be furnished in either pendent type for rigid conduit mounting or with ceiling junction box. Listed by Underwriters' Laboratories.



Type G "Vapor-Seal" Fixture

BENJAMIN TYPE G "VAPOR-SEAL" FIXTURE

Designed especially for Class 2, Group G, and Classes 3 and 4 Hazardous Locations. Vapor-tight threaded connection between hood and reflector. Glass cover, with gasket and aluminum pressure rings bolted to extension bead on reflector. Listed by Underwriters' Laboratories.



Type G-2 Dust-Tight Fixture

BENJAMIN TYPE G-2—DUST TIGHT FIXTURE

A new Benjamin unit to meet present Underwriters' requirements for locations where dust and inflammable particles create a fire hazard. Same type head as Type G "Vapor-Seal," but with screw thread enclosing globe. Can be furnished with or without reflector.

Write for full information on the use of lighting in hazardous locations and Benjamin fixtures which meet Underwriters' Laboratories requirements.

BENJAMIN ELECTRIC MFG. CO.

General Offices and Factory

DES PLAINES, ILLINOIS

Divisional Sales Offices

NEW YORK :: CHICAGO :: SAN FRANCISCO

Eleven

point protection

CENTRAL STATION Sprinkler Supervisory Service performs 11 important functions...in addition to notifying the fire department, automatically, quickly and accurately when water flows from the sprinkler system, it includes these essential safeguards:

IT AUTOMATICALLY REPORTS:

Opening or closing of shut-off valves;
High or low air pressure in dry pipe systems;
High or low water in gravity tanks;
Low temperature in gravity tanks;
High or low air pressure in pressure tanks;
High or low water in pressure tanks;
Power supply to fire pumps cut off.

All electrical circuits are under the constant supervision of the Central Station.

A. D. T. assumes full responsibility for the inspection and maintenance of the entire supervisory system.

Every alarm is investigated immediately by A. D. T. Central Station operatives and is followed closely until normal conditions are restored.

94,230 sprinkler waterflow and supervisory signals were received in A. D. T. Central Stations during 1933... all indicated conditions requiring immediate correction and were speedily and effectively acted upon.

11 POINT PROTECTION, supplied only by A. D. T. Service, assures instant automatic reporting of fires and that sprinkler systems receive the care and attention necessary for successful operation. We shall be glad to send you descriptive literature.

CONTROLLED COMPANIES OF

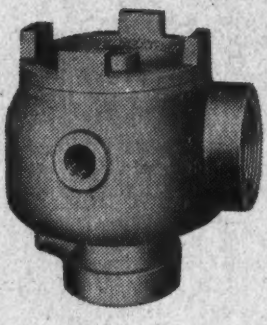
AMERICAN DISTRICT TELEGRAPH COMPANY, 155 SIXTH AVE., NEW YORK

A.D.T. *Protection* against FIRE · BURGLARY · HOLDUP

A NATION-WIDE SERVICE

THE COLD WEATHER VALVE

Converts a Section of a Wet System Into a Dry one



Insures 100% Protection to Entire Plant In Winter

No longer is it necessary to risk the danger of fire menacing an entire plant simply because a section of the wet pipe sprinkler system has been shut off to prevent freezing in an unheated section of the premises during the winter months.

The Cold Weather Valve has been developed by the Automatic Sprinkler Industry, in coöperation with the Insurance Companies to enable property owners to safeguard themselves against this hazard. It performs the same service for small, unheated systems that dry pipe valves render freezing areas in large systems. Manufactured in the 2″ size only, it insures 100% protection by the automatic sprinkler system during the entire year.

The Cold Weather Valve has been approved by Underwriters' Laboratories and Factory Mutual Laboratories.

The GRINNELL Quartzoid BULB SPRINKLER

Similar in appearance and method of operation to the well-known quartz bulb sprinkler, it has all the advantages of the latter, yet costs but little more than the ordinary solder type. It carries the art of automatic fire protection to a higher degree of perfection.

GRINNELL COMPANY
INC.

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PROVIDENCE RHODE ISLAND

Offices in all Principal Cities of the United States and Canada.